AGRICULTURAL ENGINEERING

MARCH • 1955

In this Issue . . .

Hydraulic Motors for Agricultural Machines —a Challenge for Design Engineers

•

Agricultural Engineers Report on Extensive Experiments in Hay Crushing

•

Engineering Aspects of Controlled-Atmosphere Storage of Fruits and Vegetables

•

Water Cooling of Beef Cattle Under Hot Weather Conditions

•

Pasture Irrigation Found Profitable Under Good Management Practices

ASAE 48th Annual Meeting • Urbana, Ill., June 12-15

THE JOURNAL OF THE
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Farming Moves Forward ... with Grass

Whether for green feed, silage or hay, grasses and legumes are playing a big role in the shift to grassland farming . . . greater conservation of soil and water . . . more efficient utilization of forage crops that have been developed for rich and succulent livestock feed as well as guardians of natural agricultural resources. Yet, these crops cannot make their full contribution to better farming by lush growth and as a feed unless they are *harvested fast* at just the right stage for best nutrition and storage . . . *harvested at low cost* to hold down ration expense . . . *harvested with a mechanical ease* that spares the operator's strength and saves him time when labor is scarce. That's why Case is keeping pace by building forage choppers to meet new and ever-changing forage-harvesting requirements.

America's Lightest-Running Forage Chopper

Case Forage Harvesters, reported by users as "Today's Lightest-Running Forage Choppers," push down operating expenses by saving power with an efficient low-speed knife wheel . . . oil-bath gears . . . anti-friction bearings . . . and few moving parts. There are savings in investment, too . . . because the Case base machine . . . in both 4 and 6-knife cutting-wheel models . . . takes today's widest choice of chopping attachments—regular row-crop, short-corn row-crop, corn harvester, windrow pick-up, draper-type cutter-bar or heavy-duty green-feeding cutter-bar. Then, there are substantial savings in time and labor, since one man removes or attaches quickly and easily any of the units . . . each rolling into place on the base machine or into storage on its own dolly. See your nearest Case dealer or write for loan of full-color, sound movie and take-home free booklets on "Chop the Crop" to J. I. Case Co., Racine, Wis.

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"Till death do us part" is the way CHAIN Belt Agricultural Chain Engineers look at the design of chain attachments. They believe that there can be no weak links in agricultural implement chains and attachments ... and don't stop their work until they have the answer.

This is the principal reason why Rex® Agricultural Chain attachment links deliver such exceptional service life... last for the lifetime of the chain strand. But Rex Engineers are never satisfied, and as soon as one development is completed, they go on to another. They've got a lot up their sleeves, and it will pay you to look for yourself.

Why not be sure you're up to date on all the recent developments designed to help you get more from the chains you use? Call your CHAIN Belt Man or write CHAIN Belt Company, 4680 W. Greenfield Ave., Milwaukee 1, Wisconsin, for your copy of Agricultural Chain Catalog No. 54-54.

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AGRICULTURAL ENGINEERING

Established 1920

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Mr. R. G. Folk, president of Equipment Supply Co., Inc., of El Paso, Texas, checking some orders. His company serves West Texas, Southern New Mexico and Northern Mexico.

Inviting customers to call collect brings parts sales of $4000 first month

To give customers quick, dependable parts delivery and service, the Equipment Supply Co. invites its United States customers to call collect by Long Distance.

In the first month of the Call Collect Plan, sales of $4000 in parts were attributed to calls *costing only $60.* And the plan is doing more than building parts sales.

"We know that *new tractor sales* have increased due to this promise of good service," the company reports. "We have gained many new customers as well as improved relations with our old customers."

You can start a similar plan today. The only equipment you need is the telephone on your desk. And there are many other ways you can make Long Distance increase sales. If you would like a telephone company representative to stop in and explain them, call your Bell Telephone Business Office.

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In the plow shown below, as well as in other J. I. Case equipment, Peoria Malleable castings meet exacting specifications for precision, quality and durability. And J. I. Case Company is but one of many leading farm equipment manufacturers who are Peoria Malleable castings customers for levers, covers and other parts.

Peoria Malleable Castings provide strength and dependability in a cleanly-designed, good looking part that often is less costly than the production expense of a weldment or a forging.

Your letter brings complete information... or your specifications bring a definite quotation, at no obligation.

A big part of **QUALITY** *is a* **QUALITY** *part*

STANDARD OR PEARLITIC

PEORIA MALLEABLE CASTINGS CO.

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FAMOUS FOR **QUALITY**

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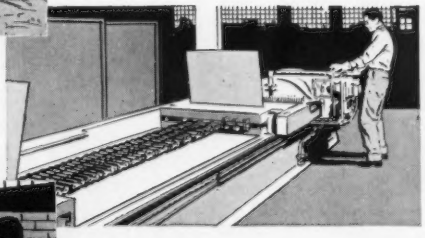
ANY SHORTCOMING in machine performance —whatever the cause—reflects on the maker. That's why so many farm machinery manufacturers standardize on Link-Belt chain for long life and added dependability. Exact manufacturing controls and thorough testing assure maximum chain strength and uniformity . . . contribute to the overall quality of your machine.

so it's good business to rely on LINK-BELT

EXPERT ENGINEERING AND FIELD TESTING. Link-Belt's engineering staff is unequalled in ability and experience. Design innovations are continually recommended and thoroughly field-tested. Many universally-used chain developments were born at Link-Belt.

COMPLETENESS ASSURES LOW-COST, PRACTICAL ANSWERS. With Link-Belt's broad lines of chain, sprockets and attachments, farm machinery manufacturers are sure to find the right answer for each application.



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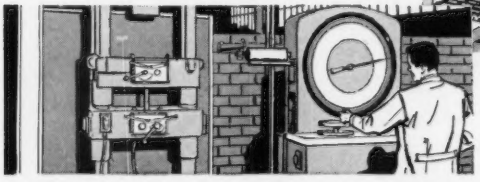

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Simplified design of new Lundell Implement employs Dayton V-Belts to gain maximum power

Combination Shredder and Hay Chopper, engineered with only 3 working parts, gets top performance through use of harder-gripping, Dayton raw-edge V-belt drives.

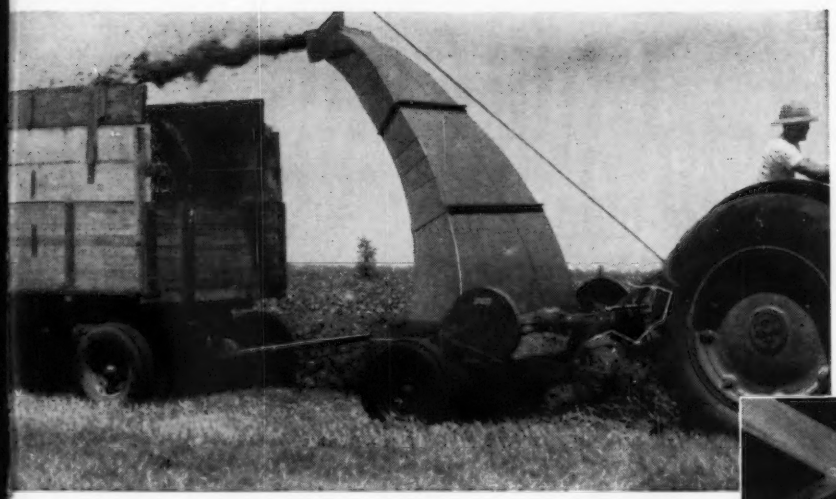
In developing this new combination unit Lundell Manufacturing Co. engineers parlayed design "know-how" and past experience into increased productivity at lower original and replacement cost.

Design "know-how" enabled them to build an implement, with only 3 working parts, that is setting new records in chopping hay, shredding stalks, chopping stalks and vines for bedding and preparing crops for silage. Result: a Combination Shredder and Hay Chopper which, because of its simplicity of design, costs less to buy, less to operate.

Past experience played an important part in developing the unit because of the success achieved by Dayton V-Belts on all other Lundell implements.

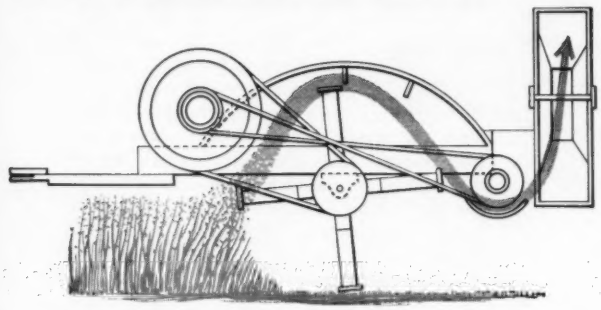
There was no need for Lundell engineers to spend weeks in research to find an adequate source of economical power. Dayton raw-edge V-Belts were installed as a matter of policy and proved their worth at once. The die-cut, raw-edge sides provided the necessary rubber-to-metal contact to grip pulley grooves tenaciously, hold on despite tremendous shocks under all conditions and deliver full power.

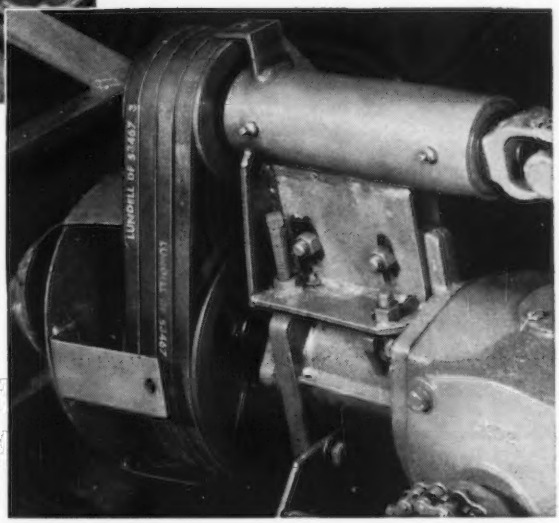
Photos courtesy Lundell Manufacturing Co., Cherokee, Iowa.



Lundell Economy Hay Chopper line also Dayton-equipped

Lundell engineers have given the same attention to power transmission on this Economy Hay Chopper by specifying Dayton Agricultural V-Belts for all drives. Designed and built to provide greater chopping capacity, this Economy Hay Chopper has an extra large throat area, wide cutting width and Dayton V-Belt-driven cutting knives.





Main cylinder drive

Four matched Dayton raw-edge V-Belts transmit an even, steady flow of power from the take-off shaft to the main cylinder. Two matched Daytons drive the cylinder equipped with hammer like knives for cutting and chopping and a second set powers the auger or blower.

Dayton V-Belts provide *extra* power

Nine Dayton raw-edge V-belts transmit all the power needed, and MORE, to drive this hard-working combination unit. Chief reason why they fill the bill so successfully is the high coefficient of friction resulting from rubber-to-metal contact. The contact, provided by the exclusive die-cut, raw-edge construction, makes it possible to pull greater loads with less tension. This assures maximum power, longer life and less frequent replacement. Why not see how Dayton V-Belts can improve *your* product. Write to Dayton Rubber Co., Agricultural O.E.M. Division, Dept. 402, 1500 S. Western Ave., Chicago, Ill.

Dayton V-Belt has exclusive features

This die-cut, raw-edge Dayton V-Belt provides perfect rubber-to-metal contact, without slippage, due to high coefficient of friction. Ruggedly constructed, the load supporting members extend the full width—from one side of pulley to the other.

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Dayton Rubber

Since 1905

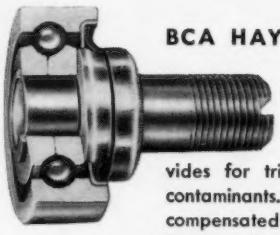
First in Agricultural V-Belts

Agricultural Sales Engineers in Chicago, Moline, New York, San Francisco, Cincinnati and St. Louis

Specify BCA Ball Bearings

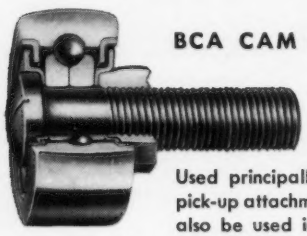
the low-cost, pre-lubricated "package units" specifically designed for agricultural service

Now, farm implement manufacturers can make the most of the many advantages of ball bearings. BCA Agricultural Bearings are designed to simplify installation problems, reduce maintenance, and bring ball bearing costs down to practical levels. BCA pre-lubricated *package units* combine bearing, housing, and an effective seal in a single, rugged unit—built to cope with the loads, speeds, and operating conditions encountered in agricultural service.



BCA HAY RAKE BEARINGS

Ease of installation and design efficiency of this low-cost *package unit* has attracted wide attention. Patented design provides for triple barrier against entrance of contaminants. Misalignment of tine bar can be compensated for without detrimental effect to bearing. Proved in actual applications—in all kinds of weather, under all soil conditions. Shank length, diameter, and thread can be varied to fit specific requirements.

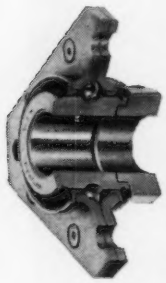


BCA CAM FOLLOWERS

Package unit includes pre-lubricated bearing, seals, cam roller, and mounting stud—all assembled, ready to install. Used principally in hay balers, or whenever pick-up attachments are adopted. Bearing may also be used in roller type conveyors. Thick-sectioned outer race is case hardened to withstand shock, and is slightly convex to assure better contact with cam.

BCA IDLER PULLEY ASSEMBLIES

Pulley, bearing, and seal—all in one complete *package unit*. Pre-lubricated bearing effectively sealed against dust and grit. Simple, rugged construction eliminates frequent field servicing. Adaptable to many agricultural applications, including: combines, forage harvesters, corn pickers, hay balers, grain elevators, cotton pickers. Idler design can be varied for use with flat belts, V-belts or chains.



BCA FLANGE BEARINGS

These simple, low-cost, pre-lubricated *package units* are sealed against water, dust, and dirt. Bearings are simply and economically mounted on commercial shafts. Flange is easily bolted to the equipment. A twist of the eccentric ring locks the bearing to shaft without need for machining the shaft. Built to give dependable service under the most severe agricultural operating conditions.

BCA PLUNGER ROLLERS

Built with a thick-sectioned outer ring, hardened throughout, these *package units* are specially adapted for sliding heavy masses on rails. Principal application is in hay baler plungers, replacing plastic and metal liners, and ending the problem of wear and constant replacement. Bearings come in two types: for flat tracks, and for V-shaped tracks.

BCA

If you've got a bearing problem, contact:

BEARINGS COMPANY OF AMERICA

DIVISION OF FEDERAL-MOGUL CORPORATION

LANCASTER • PENNSYLVANIA

Pioneers of pre-lubricated *package unit* ball bearings for agriculture

NEW!

ARMCO ALUMINUM-COATED STEEL

for outdoor service

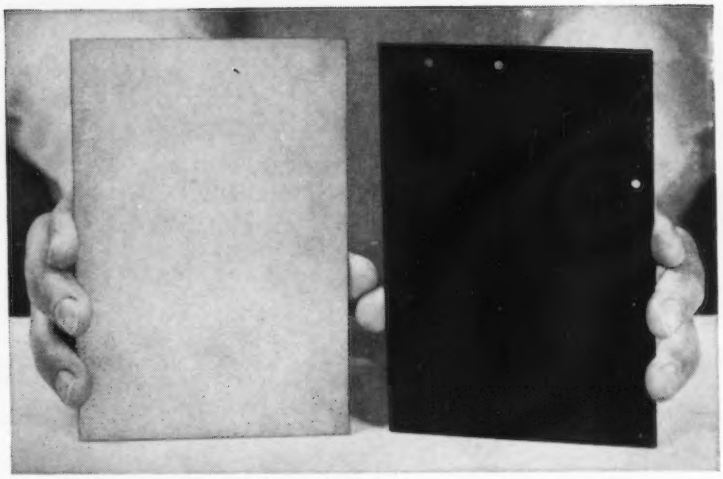
Combines Corrosion-Resisting Properties of Aluminum with Strength of Steel

A new hot-dip aluminum-coated sheet steel—known as Armco ALUMINIZED STEEL® (Type 2)—is now in production after 15 years of corrosion testing. It combines the surface advantages of aluminum with the strength of steel.

While zinc coatings have done a good job of protecting steel against rust, tests indicate this new aluminum-coated steel is greatly superior. The 15-year tests in an industrial area show the atmospheric corrosion resistance of this aluminum coating is at least 3 times that of a standard coating on galvanized steel sheets.

During the past year and a half of field development work, ALUMINIZED STEEL (Type 2) has been used in prefabricated industrial, commercial and farm buildings, industrial rolling doors, covers for silos and water storage tanks, roof deck, and other applications under general atmospheric conditions.

The new sheet is a companion grade to Armco ALUMINIZED STEEL (Type 1) exclusively produced by Armco since 1939 for high temperature service.



In atmosphere sufficiently corrosive to cause a standard galvanized coating (right) to fail completely in 12 years, Armco ALUMINIZED STEEL (Type 2), left, looked like this *after 15 years*. Cleaned samples show the aluminum coating is still giving full protection to the base metal.

QUESTIONS YOU MAY WANT ANSWERED

DOES IT "WEATHER" LIKE ALUMINUM?

Yes. The surface of samples of Armco ALUMINIZED STEEL (Type 2) and aluminum, exposed to the atmosphere for five years, cannot be told apart.

WHAT IS ITS STRENGTH?

Because it has a steel base it has the strength and rigidity of steel . . . thus avoiding problems common to weaker materials.

DOES IT REFLECT HEAT?

Yes, ALUMINIZED STEEL (Type 2) offers the same high reflectivity of radiant heat as aluminum—whether from the sun or from low temperature heat sources.

DOES IT RESIST FIRE DAMAGE?

Armco ALUMINIZED STEEL has excellent resistance to fire damage. At 800 F, for example, it has more than ten times the strength of aluminum. Steel has a melting point of 2850 F; aluminum melts at about 1200 F.

WHAT ABOUT FABRICATION?

Armco ALUMINIZED STEEL (Type 2) withstands severe forming without peeling or flaking of the coating. It also can be embossed and spun, but is not recommended for drawing operations.

HOW DOES IT COMPARE IN COST?

Even when considering equal thicknesses, ALUMINIZED STEEL (Type 2) generally costs less per square foot than aluminum. Additional cost savings are possible because the greater strength of the steel base permits use of lighter gages. For example, a fabricator using .050 aluminum could save 40 to 50 per cent of material costs by utilizing the proper gage of ALUMINIZED STEEL.

While the initial cost is somewhat higher than galvanized steel, it is less than the cost of galvanized plus one field coat of paint. Because of its superior atmospheric corrosion resistance, the new aluminum-coated steel needs no paint protection.

If you would like complete information on sizes, gages and prices of Armco ALUMINIZED STEEL (Type 2), just fill in and mail the coupon.

ARMCO STEEL CORPORATION
975 Curtis Street, Middletown, Ohio

Sheffield Steel Division • Armco Drainage & Metal Products, Inc. • The Armco International Corporation

ARMCO®

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What are sizes, gages and prices of Armco ALUMINIZED STEEL (Type 2)?

We manufacture_____

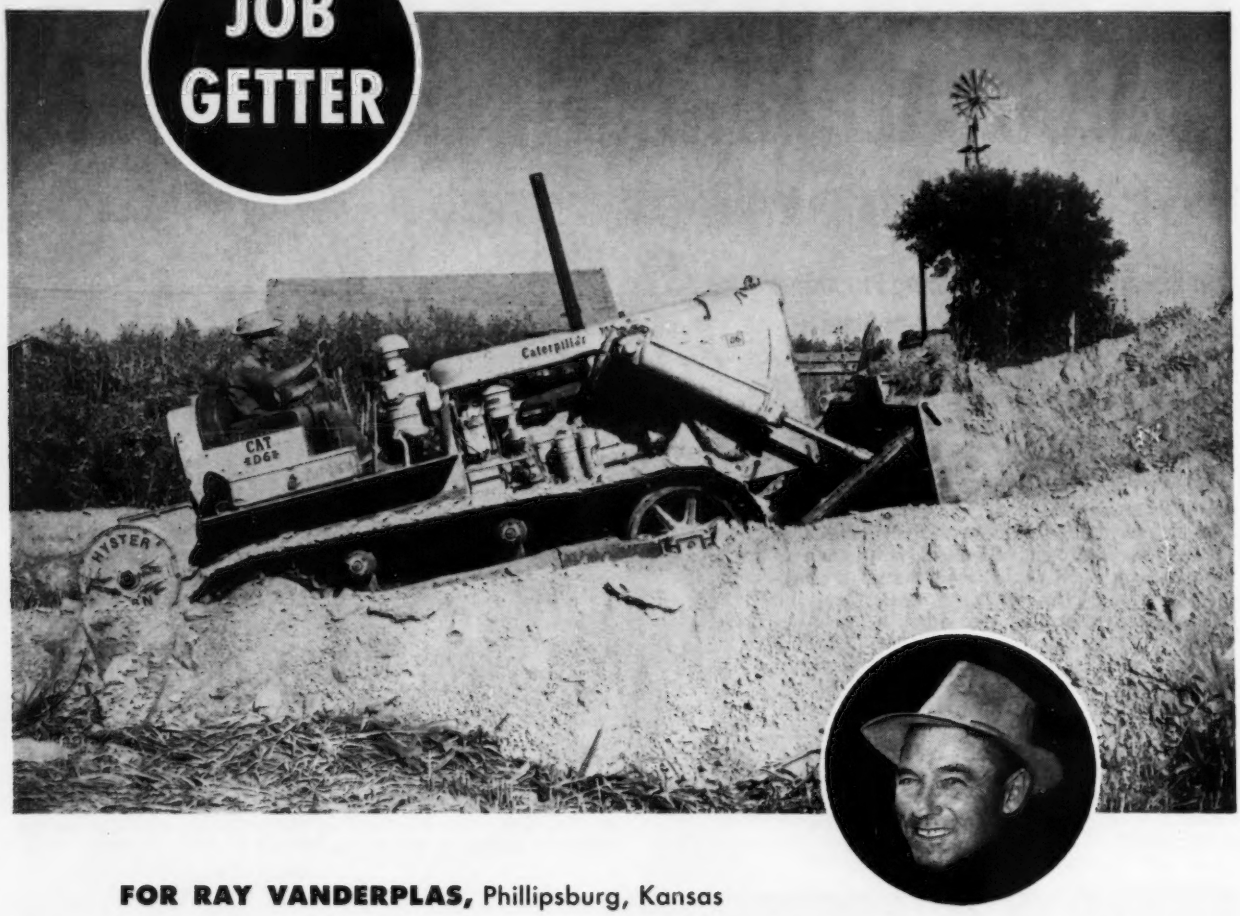
Name_____

Title_____ Company_____

Street_____

City_____ Zone_____ State_____

JOB GETTER



FOR RAY VANDERPLAS, Phillipsburg, Kansas

"It's easier to find jobs . . . when you've a CAT® Diesel Tractor. Farmers like to get their money's worth . . . that's why we've a Cat Diesel Tractor! They know they're getting the best and there's no argument about who will get the job. I chose the Cat Diesel Tractor because it's cheap to maintain and is backed by good dealer service!"

* * * * * * * *

Look who's getting the jobs in your community . . . most of the time it's the man with Caterpillar equipment. The Caterpillar owner knows he can run his machines at full throttle day in, day out . . . and he does. No babying. No half-throttle operation needed to "give his machine a rest." Farmers know this, too. They're willing to pay $10 – $15 – $20 per hour when they know they get full value. That's why they go to the man with Caterpillar Diesel Tractors, Motor Graders and Earthmoving Equipment.

You'll not only get more jobs with Cat equipment, but you'll make a lot more money, too. You burn low-cost, powerful No. 2 furnace oil without fouling. Extra-quality design and manufacture make your machine last longer, cost less to operate.

It'll pay you to make your Caterpillar Dealer headquarters for both new and used machinery! Caterpillar Tractor Co., Peoria, Illinois, U.S.A.

CATERPILLAR®

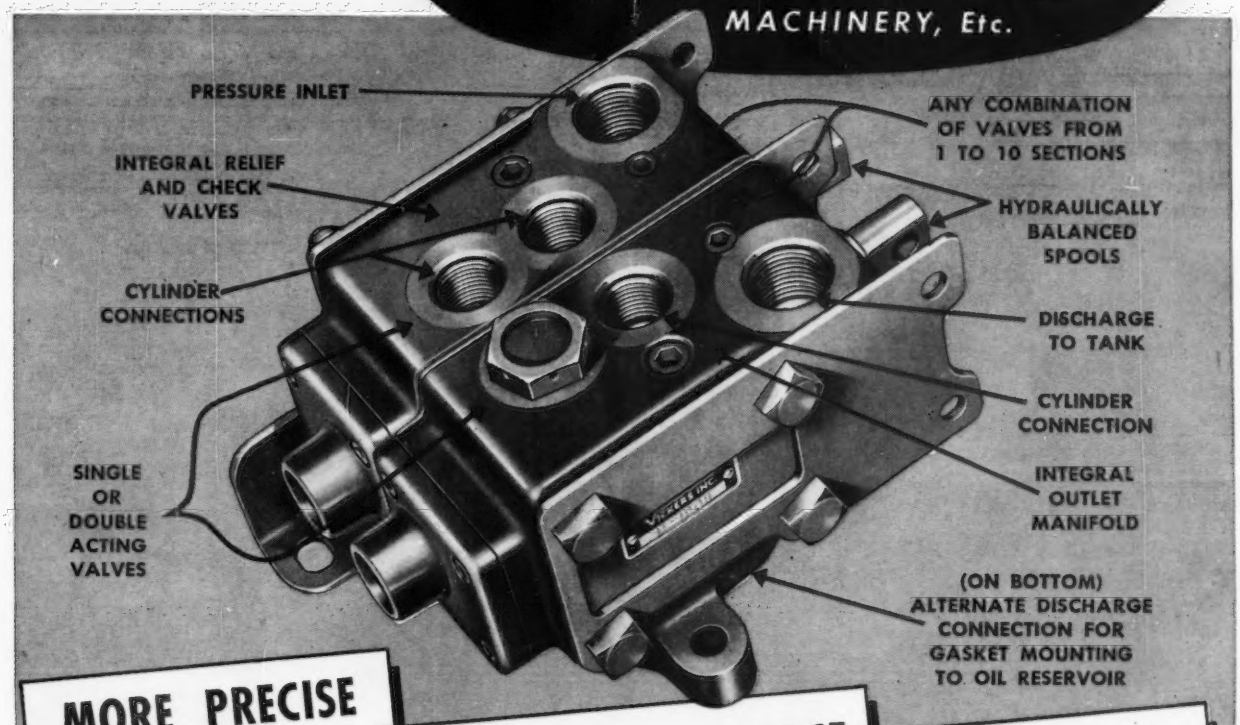
Cat Products have moved more dirt . . . cleared more land than any other man-made power on earth.

FREE LAND CLEARING BOOKLETS . . .

Drop us a line today telling us which copies you want: "Clearing for Crops," "Tailor-made for Irrigated Farming" and "Conservation Pays!" Be sure to include your name and address. Caterpillar Tractor Co., Dept. AE35, Peoria, Illinois.

NEW! Series CM11 VICKERS® MULTIPLE UNIT VALVES

For MATERIALS HANDLING EQUIPMENT, FARM TRACTORS, BUCKET LOADERS, CONSTRUCTION and MINING MACHINERY, Etc.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INTEGRAL RELIEF AND CHECK VALVES
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ANY COMBINATION OF VALVES FROM 1 TO 10 SECTIONS
HYDRAULICALLY BALANCED SPOOLS
DISCHARGE TO TANK
CYLINDER CONNECTION
INTEGRAL OUTLET MANIFOLD
(ON BOTTOM) ALTERNATE DISCHARGE CONNECTION FOR GASKET MOUNTING TO OIL RESERVOIR

MORE PRECISE CONTROL
Improved Metering Characteristics

REQUIRES LESS SPACE
New Combination Operating-Valve and End-Plate Sections

LOWER COST
Simplified Design and Construction

New, compact, more versatile design of valve. End sections combine in one casting the inlet or outlet manifold plate together with any operating-valve section. Inlet section also contains relief valve. Individual outlet plates available for single unit valves. Single- and double-operating valve sections can be added between end sections as needed. Valve can be adapted for tandem (series) operation. Single-acting valves available for either direction of lever shift.

Other features include protection of pump from reverse flow during shifting . . . three point mounting for more simple installation . . . cylinder connections with ¾-16 N.F.-2 straight threads (AND 10050 type) which conform to SAE standards help insure leak-proof connections . . . optional outlet ports in end section so valve can be gasket mounted to the oil reservoir or pipe connected. Designed for use with Vickers Series V-200 Vane Pumps (up to 11 gpm), the CM11 Valve can be used up to 2000 psi working pressure. For further information write for Installation Drawing M168643.

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ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921

Here's a bolt whose weakness is its strength!

Making a bolt that fails precisely when it should requires specialized manufacturing skills.

This is the job New Holland Machine Company, farm equipment manufacturers, turned over to RB&W. The bolt is used on the flywheel of a New Holland baler. "Critical" is a weak word for its importance to the baler.

If the baler picks up a foreign object such as a rock or stone, this bolt *must* snap to prevent gear breakage. But it can't fail too soon—when the baler eats up extra-heavy windrows, for example. If it failed every time this happened, the farmer would spend all day replacing bolts — instead of making hay.

RB&W worked hand-in-glove with New Holland engineers in the tough job of heat-treating a standard machine bolt to these exacting specifications. It took a lot of ingenuity — but paid off. You can expect the same kind of service, cooperation and end product when you drop your fastener problem in our hopper. RUSSELL, BURDSALL & WARD BOLT AND NUT CO., Port Chester, N.Y.

UP TO TWELVE TONS OF HAY AN HOUR is the capacity of New Holland's Super 77 power take-off baler. With every minute vital in harvesting, farmers can't take chances on machinery failure — so New Holland built rugged parts into the Super 77, gave it extra-large capacity for fast, reliable operation.

RB&W **RUSSELL, BURDSALL & WARD**

110 YEARS MAKING STRONG THE THINGS THAT MAKE AMERICA STRONG

Plants at: PORT CHESTER, N.Y.; CORAOPOLIS, PA.; ROCK FALLS, ILL.; LOS ANGELES, CALIF. *Additional sales offices at:* ARDMORE (PHILA.), PA.; PITTSBURGH; DETROIT; CHICAGO; DALLAS; SAN FRANCISCO. *Sales agents at:* NEW ORLEANS, DENVER, SEATTLE. *Distributors from coast to coast.*

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For the very latest in design and highest quality workmanship — America's leading automobiles rely on MECHANICS. MECHANICS drive lines are engineered to meet each customer's specific needs. Torque, size, weight, balance, angularity, runout, safety, lubrication, assembly and service problems all have been overcome — to each customer's complete satisfaction. Let us help engineer joints and drive lines to fit Your products.

MECHANICS UNIVERSAL JOINT DIVISION
Borg-Warner • 2046 Harrison Ave., Rockford, Ill.

MECHANICS
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UNIVERSAL JOINTS

For Cars • Trucks • Tractors • Farm Implements • Road Machinery • Aircraft • Tanks • Busses and Industrial Equipment

An attitude and an aptitude for solving bearing problems . . .

Fafnir Flangette, a pre-lubricated, completely packaged unit.

FAFNIR
BALL BEARINGS

To break the cost barrier limiting the use of ball bearings on farm equipment, Fafnir developed the Flangette, a unique ball bearing power transmission unit. Its initial cost is low. Its simplified construction assures easiest installation and removal. Costs are lowered two ways.

The Flangette is typical of Fafnir developments made possible by an experience which is over 40 years long and industry wide. Maybe this "economy package" or some similar Fafnir Development can help you break a cost-barrier. The Fafnir Bearing Co., New Britain, Conn.

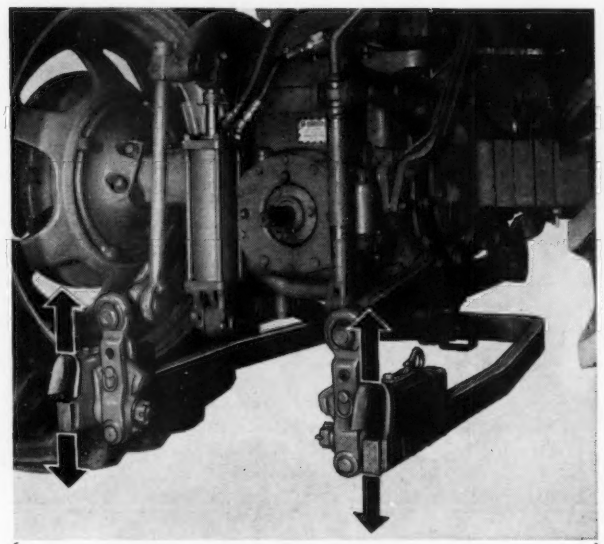
MOST COMPLETE LINE IN AMERICA

A report to you about men and machines that help maintain International Harvester leadership

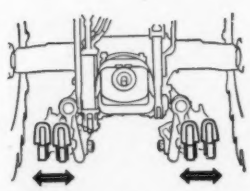
Simply backing the tractor engages Fast-Hitch sockets with implement coupling beams to make a self-locking, super-strong, direct connection.

How back . . . click . . . and GO Farmall® Fast-Hitch improves quality of implement performance

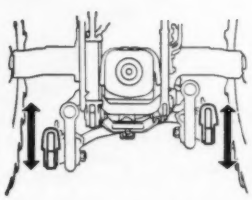
The ability to Back . . . CLICK . . . and Go! with Farmall Fast-Hitch is a time and work-saving advantage instantly understood by any farmer. Less obvious, but of *even greater importance*, is the complete adjustability of Fast-Hitch to *every* requirement for top quality work with any McCormick® Fast-Hitch implement—ranging from completely directed control to completely free "float". The illustrations below show why, *for the first time*, Fast-Hitch overcomes implement operating limitations of other hitching methods.



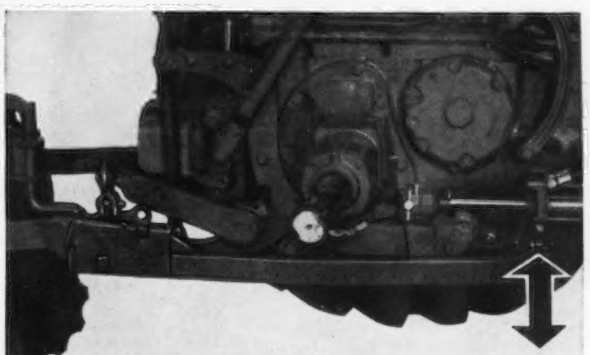
Fast-Hitch allows implements to float freely up and down. Or, the implement or Fast-Hitch drawbar can be held at any selected height within a wide vertical range.



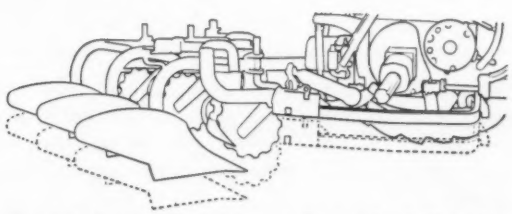
Fast-Hitch can be locked rigid, side-to-side, or allowed to swing free, as illustrated.



Fast-Hitch can be quickly tilted and leveled, or allowed to float diagonally.



Only Fast-Hitch has a single draft point instantly raised, lowered or held firmly with hydraulic power at selected height (manually on the Farmall Cub®).



Changing draft point height changes plowing depth. Plow always works in the true line of draft, resulting in remarkably uniform work, even though the tractor wheels ride over uneven ground.

IH engineering teamwork produced Fast-Hitch for the five new McCormick Farmall tractors—"the greatest line of farm tractors on earth." IH research, engineering, and manufacturing men are constantly pooling time and talent to provide equipment of improved performance, making the farmer's work easier while boosting production.

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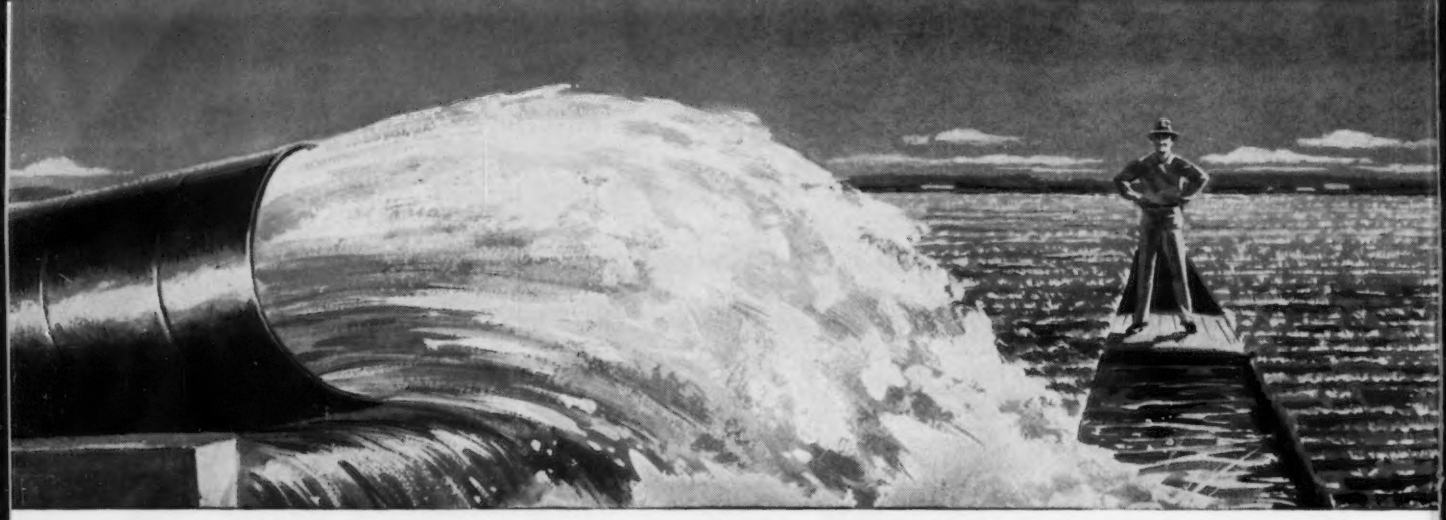
International Harvester products pay for themselves in use—McCormick Farm Equipment and Farmall Tractors . . . Motor Trucks . . . Crawler Tractors and Power Units . . . Refrigerators and Freezers—General Office, Chicago 1, Illinois.



576 million gallons of water in 9600 hours

. . . that's average for a Chrysler Industrial V-8-powered irrigation pump in West Texas

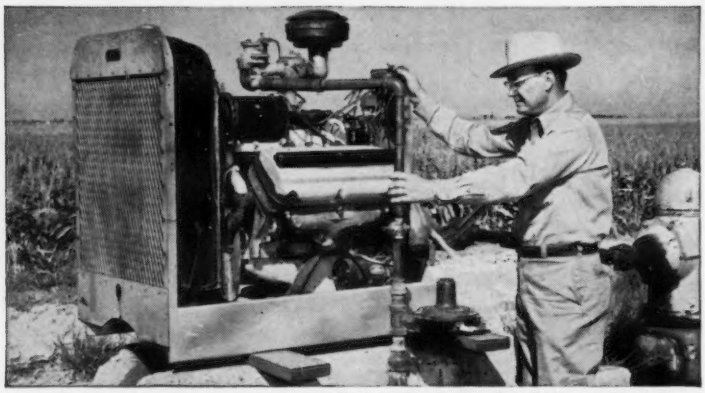


Photo courtesy Louthan-Dowell Motors, Lubbock, Texas

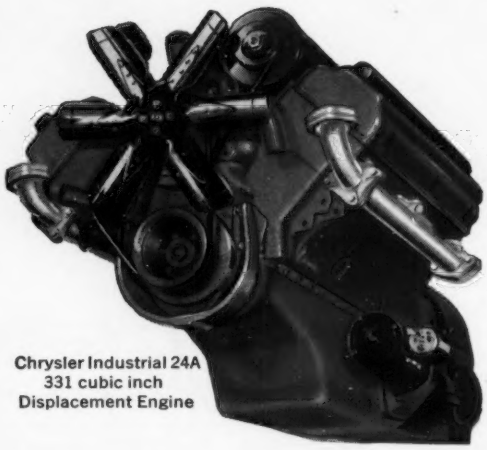
Lloyd Huffaker, Lubbock, Texas, stands beside his Chrysler Ind. 24A-powered irrigation pump. In 2½ years, Mr. Huffaker has irrigated three crops of cotton, maize and alfalfa, his pump and Chrysler Industrial Engine operating approximately 133 twenty-four hour days during each season. Pump has delivered an average of 1000 gallons per minute, for a grand total of 576,000,000 gallons of water. Total maintenance repair in 2½ years: One set of spark plugs and three sets of points installed at total cost of $10.00. If the total revolutions this engine has turned were reduced to miles, they would equal approximately 336,000 miles—or more than thirteen times around the world.

Ask any grower in West Texas what the local performance record for an irrigation pump is and, chances are, he won't know . . . records are broken every day in Texas. He just assumes his pump will bring water up approximately 320 feet in sufficient quantity to irrigate his entire crop every day of his 120 to 200 day growing season.

But ask any West Texas grower *what engines* power his irrigation pumps, and if he's like better than 85% of West Texas growers, he'll tell you — Chrysler Industrial. And if you ask him why, you will get an answer based upon better than fifteen years experience — his own and his neighbors'.

For instance, a West Texas grower might tell you that, among lightweight high-speed engines operating on either butane or natural gas, Chrysler is the only engine equipped with all the truly *industrial* engine features. As examples he could mention features like sodium-cooled exhaust valves with extra-hard stellite valve heads and valve seats, heavy duty induction hardened crankshafts and large tri-metal bearings. Finally he would probably point out that a single Chrysler Industrial Engine has been driving his centrifugal pump nearly ten years without a major overhaul while during the same period competitive power plants may likely have required two or three overhauls.

If it's real industrial power *you* need . . . for irrigation or any other equipment, you can't buy an industrial engine to equal Chrysler, 230 to 413 cubic inches displacement. For details, see a Chrysler Industrial Engine Dealer, or write: ***Dept. 173, Industrial Engine Division, Chrysler Corporation, Trenton, Michigan.***

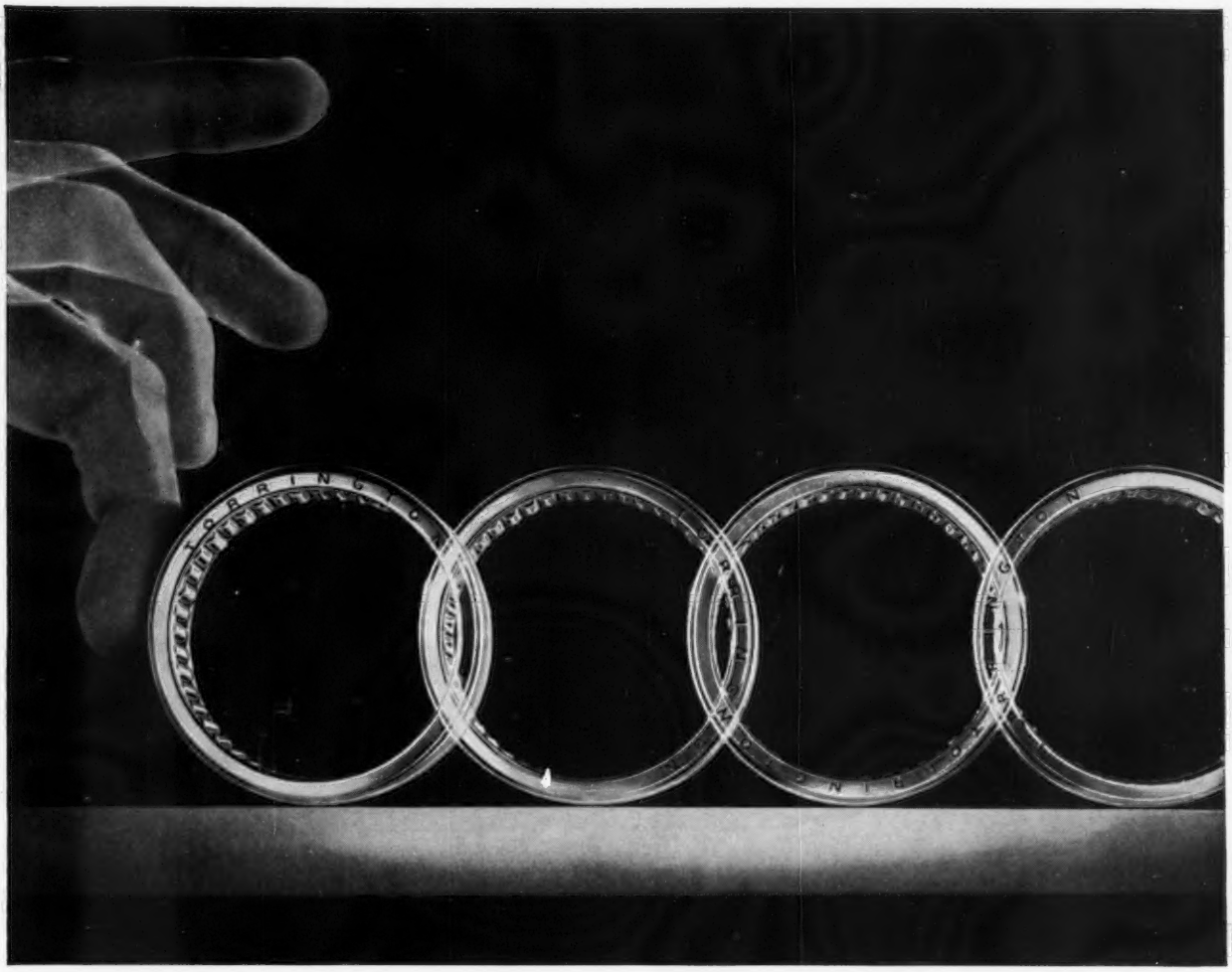


Chrysler Industrial 24A
331 cubic inch
Displacement Engine

CHRYSLER
Industrial Engines

INDUSTRIAL ENGINE DIVISION • CHRYSLER CORPORATION

HORSEPOWER WITH A PEDIGREE



"It takes less push . . . to start a **TORRINGTON NEEDLE BEARING"**

The Torrington Needle Bearing has a low coefficient of friction—both in starting and in running. Therein lies a boon for designers and manufacturers.

Unlike a plain bearing which has a fairly high starting coefficient of friction—the Needle Bearing needs no more push to "get it going" than to "keep it going."

Nor are the frictional characteristics of the Needle Bearing dependent upon maintaining a continuous oil film as is a plain bearing. This all adds up to inexpensive and simpler designs, smaller drive motors and dependability.

For twenty years our engineering department has helped designers and manufacturers throughout industry to adapt the unique characteristics of the Needle Bearing to their products. Let us help you make the Needle Bearing "standard equipment" in yours.

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TORRINGTON *NEEDLE* **BEARINGS**

Needle • Spherical Roller • Tapered Roller • Cylindrical Roller • Ball • Needle Rollers

These features make the **TORRINGTON NEEDLE BEARING** *unique*

- low coefficient of starting and running friction
- full complement of rollers
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- low unit cost
- long service life
- compactness and light weight
- runs directly on hardened shafts
- permits use of larger and stiffer shafts

Thompson's CREATIVE CASTING OFFERS YOU BETTER PISTONS

Diesel Heavy-Duty Piston

Aircraft Piston

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"M" Tractor Piston

Steel-Belted Piston

OVER 50 YEARS of making precision parts for the automotive and aircraft industries . . . has given Thompson engineers opportunities to improve on many methods and materials.

"Creative Casting"—a Thompson development—makes possible the use of metals that withstand high temperature—that are strong—that are lightweight and can be cast to very close tolerances.

Whether it's a piston for an airplane, a passenger car, a heavy-duty truck or tractor engine—gasoline or diesel—you'll find that Thompson's Light Metals Division can make it better. Thompson's famous STEEL-BELTED PISTON is one example of a Thompson FIRST that gives better engine performance in cars, trucks, buses and tractors. Write or call and a competent representative will call to help you solve your piston problems.

For a detailed description of the Thompson Light Metals Division operations, send for your free copy of "Creative Castings". "Steel Belted Pistons", detailing this Thompson development, is also available. Just write, on your company stationery, to Dept. AE-1 Light Metals Division, Thompson Products, Inc., 2269 Ashland Road, Cleveland 3, Ohio.

You can count on

Thompson Products

LIGHT METALS DIVISION

2269 Ashland Road Cleveland 3, Ohio

When the J. I. Case Company decided to bring the benefits of diesel power to their largest tractor unit, they needed a final drive to transmit high horsepower, to withstand severe chordal action and high shock loading, and most important—to be compact enough to fit within the rigid limits set for the transmission case.

Exhaustive field tests showed that a 2″ pitch Morse High Endurance Roller Chain was ideally suited to the job.

How Morse High Endurance Roller Chain solved a problem on big diesel tractor

Perhaps you, like the J. I. Case Company, have a design problem which can be solved by using Morse High Endurance Roller Chain. If you have increased power transmission requirements, don't change your design . . . check the possibilities of High Endurance Roller Chain to meet your higher power requirements.

Morse High Endurance Roller Chain is the finest available. It is built with particular attention to (1) wear life between bushing and pin; (2) pin retention; (3) bushing retention; (4) impact resistance of the rollers; (5) structural fatigue resistance strength of the plates.

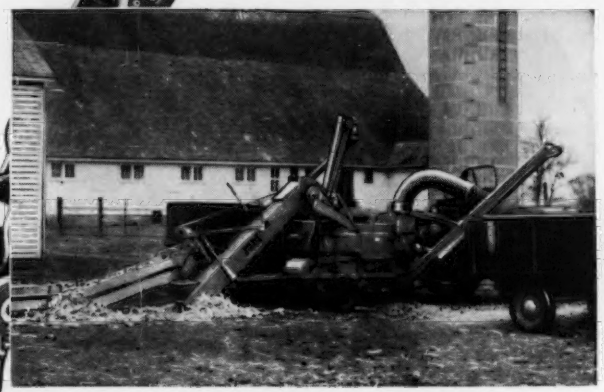
Add to this the factors of fine-grain alloy steel, precision manufacturing, shot peening, and strict quality control —and you have some of the reasons Morse High Endurance Roller Chain is outlasting standard roller chain on some applications by 100% or more. By simply changing the chain, you can realize important savings.

Check Morse High Endurance Roller Chain. Check, too, the other lines of precision-built Morse Power Transmission Products: Roller Chain, Stock Sprockets, Couplings, Cable Chain, and Clutches. Write for further information; Morse engineers will be happy to discuss your power transmission needs with you. MORSE CHAIN COMPANY, 7601 CENTRAL AVE., DETROIT 10, MICHIGAN.

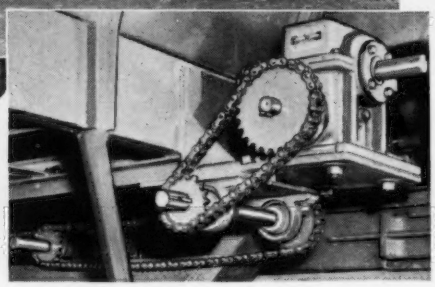
MORSE BW **CHAINS, CLUTCHES AND COUPLINGS**

MODERN HIGH SPEED FARM MACHINES

LIKE THE MINNEAPOLIS-MOLINE SHELLER



AND THE CROSE AUTOMATIC FEED WAGON



HAVE ONE THING IN COMMON

BOTH ARE EQUIPPED WITH

DIAMOND ROLLER CHAINS

Like other industries, agriculture demands speed, higher efficiency and reliable performance. Builders of modern machinery and equipment have found Diamond Roller Chains not only aid in the design but provide the long-life dependable power transfer needed to increase speed and production. Minneapolis-Moline Shellers and Crose Automatic Feed Wagons are two examples of thousands, where Diamond has met field and operating conditions so satisfactorily.

DIAMOND CHAIN COMPANY, Inc.

Where High Quality is Traditional

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Offices and Distributors in All Principal Cities

Please refer to the classified section of your local telephone directory under the heading CHAINS or CHAINS-ROLLER

DIAMOND ROLLER CHAINS

Quick Diggers, all
—and all use BLOOD BROTHERS UNIVERSAL JOINTS from the P.T.O.

B.M.B. Company, Inc.

Danuser Machine Co.

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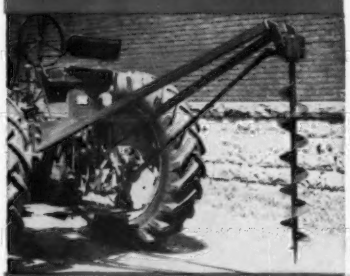


Duplex Mfg. Co.

Yes, every one of these leading manufacturers of post hole diggers* specify dependable Blood Brothers Universal Joints!

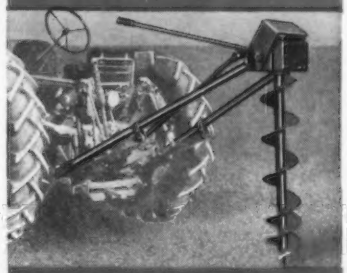
And further, many feature the Blood Brothers name in their sales literature . . . proof that "Blood Brothers Equipped" adds extra prestige, extra assurance of quality to the dealer and farmer.

Be sure you enjoy the maximum sales appeal (and dependable performance) that "Blood Brothers Equipped" can give your implements —hole diggers or any other type. Write or phone for specific data.

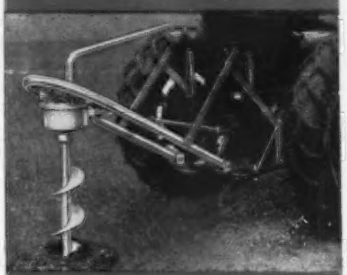
*Ideal for setting nursery stock, too!

FOR FARM IMPLEMENTS, MORE BLOOD BROTHERS UNIVERSAL JOINTS ARE USED THAN ALL OTHER MAKES COMBINED.

Standard Steel Works

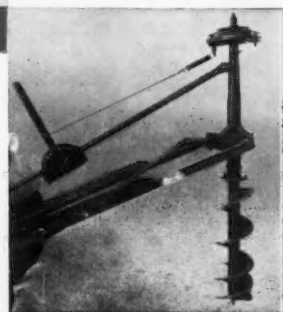


Ottawa Warner Corp., Inc.

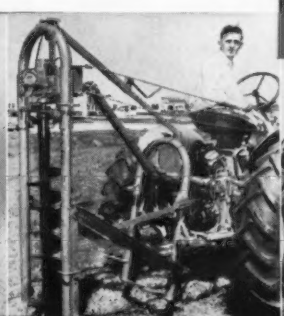


Winpower Mfg. Co.

Alexander Mfg. Co.



Paul S. Neal & Son



Continental Bolton Co.

Twin-Draulic, Inc.

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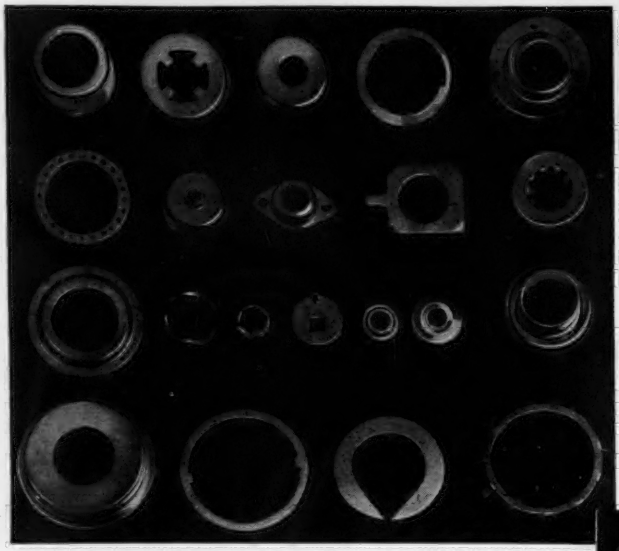
UNIVERSAL JOINTS AND DRIVE LINE ASSEMBLIES

LEADERSHIP *Backed by*

68 Years of Continuous Service to American Industry

MILWAUKEE WROT WASHERS



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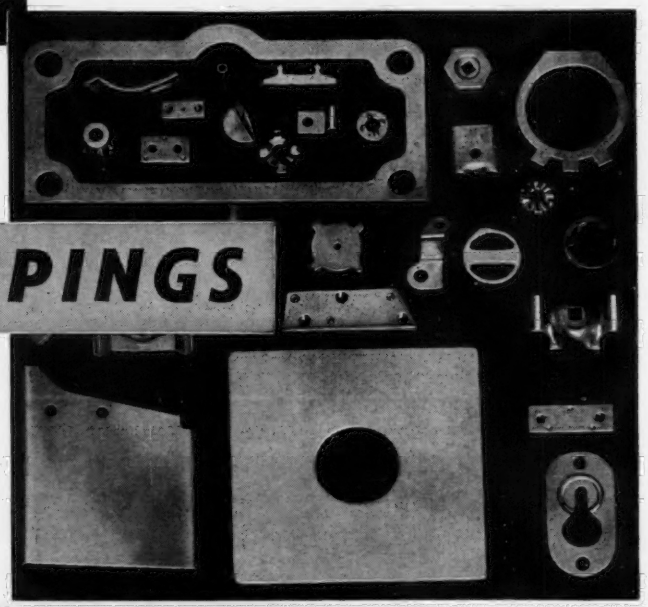
In terms of "satisfaction to the customer" the dominant leadership of Wrought Washer Mfg. Company in this specialized field represents not only a thoroughly dependable source of supply to meet all your requirements for Standard and Special Washers, but of equal importance, it carries with it a wealth of technical know-how dealing with a wide variety of production and design problems . . . available to you as a gratis service. More than 25,000 sets of dies "in stock" at our plant offer the greatest range of selectivity.



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Our equipment for handling contract production of stampings includes presses for blanking, forming, drawing, shearing and extruding. In many cases it is possible to produce stampings at a lower cost than they can be produced in your own plant, with our own equipment. Our own tool and die-making shop enables us to make up the necessary tools to fit your specifications.

We are equipped to furnish stampings in any desired materials and finishes, ranging in size from small parts to large heavy-gauge pieces. Our engineering staff will be glad to co-operate with you in every way consistent with economical and efficient production.

• • •

Send us your blueprints for quotations on special washers and stampings made to your individual specifications. Write for copy of 76-page Catalog "30" with tool list and complete round washer specifications.

WROUGHT WASHER MFG. CO.

THE WORLD'S LARGEST PRODUCER OF WASHERS

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A8247-IP

No. 4240 Truss Frame Plow

NEW OLIVER PLOW

Gives extra clearance—all 3 ways

Here's a new plow that goes a long way toward solving the problem of trash. There's constant clearance of 7½ inches with bottoms raised—regardless of plowing depth. There's extra clearance beneath the frame beam when the plow is down . . . and extra room so trash can't hang up between the bottoms.

It's a plow that sets up with either two or three bottoms that can have 12-inch, 14-inch, or 16-inch cutting widths, using just one basic frame. Gives you the convenience of being able to change from one to the other to match the power of different tractors or the resistance of different soils.

You can "sock" this plow in deep, and hold it there—flat beam frame construction easily stands the strain. You can plow stony or stumpy soils with confidence because spring trip beams protect against damage.

This new plow joins a long line of Oliver tillage tools—plows, harrows, mounted and tool bar cultivators—that are standout values in quality of construction and for usefulness in the field.

The Oliver Corporation, 400 West Madison Street, Chicago 6, Illinois.

OLIVER

"FINEST IN FARM MACHINERY"

a great new development makes

Ingersoll Discs BETTER THAN EVER

The control balcony shown above is one of the big reasons why Ingersoll discs *work more acres in the field!* That battery of "watchmen" accurately maintains scientific control of every step in Ingersoll's exclusive heat treat process.

That's vitally important—because for each type, diameter and thickness of disc, there is only one set of heat treat time and temperature factors. Each factor must be *exactly* controlled to a pre-determined setting.

With nearly three-quarters of a century of disc-making experience, Ingersoll has developed and perfected these heat treat specifications, so that each run of any type and size disc is exactly like the one before—in quality, in toughness, in resistance to abrasion and shock.

Now another new development in heat treating makes Ingersoll discs better than ever. After years of research with major oil companies, a great improvement has been made in the quench oil used in our heat treat process. This new, better oil quench helps make even tougher, longer-lasting discs—more resistant than ever to abrasion and shock.

This is one more example of the many disc improvements pioneered by Ingersoll. To be sure of such quality for *your* customers, always specify Ingersoll discs.

Ingersoll

Heat Treated Discs

Other Agricultural Products: Spring Teeth for harrows and cultivators; Coil Spring Shanks

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Borg-Warner Corporation

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ENGINEERING B-W PRODUCTION

SPECIALISTS IN TILLAGE STEEL • WORLD'S LARGEST MANUFACTURER OF DISCS

AGRICULTURAL ENGINEERING

VOL. 36 MARCH, 1955 NO. 3

Hydraulic Motors for Farm Machinery

Robert R. Owen
Member ASAE

Hydraulic-motor applications on farm machinery offer a real challenge to design engineers, by reason of the almost unlimited possibilities that exist for increasing the output of farm workers and increasing their standard of living.

HYDRAULIC cylinders have been used on farm machinery for many years and are now widely accepted. Hydraulic motors have been widely used in other industries, but their use in agriculture has been very limited. The reasons most commonly given for this lack of use are the comparatively high initial cost and a reputed lack of efficiency. For simple machinery the relatively high initial cost may rule out the use of hydraulic motors, but for more complex machines hydraulic-motor drives may be of lower cost than mechanical components. Use of hydraulic motors should be considered in planning new designs, particularly on more complex machinery or machinery with a high annual-use factor where annual maintenance costs, the value of lost operating time, and ease of control by a single operator may be more significant than initial cost differences. The general trend to larger, more complex machines, using fewer operators increases the problem of control. Hydraulic controls located at the operator's finger tips greatly simplifies the solution to this problem, and this fact has brought the hydraulic cylinder into widespread use. The same considerations usually apply to hydraulic-motor applications.

Hydraulic motors are ideally suited to applications where power is required at a location remote from the main power plant. A pair of hoses leading from the pump located at the engine to the motor located at the power site replaces the requirement of lineshafts, bearings, universal joints and telescoping shafts or an auxiliary engine. The hoses and piping can be channeled inside frame members and the result is a neater, safer and often more efficient, loss costly design than with the use of mechanical-power transmission. This application becomes especially attractive where the power site must be moved through a wide range of positions relative to the main power plant. Installations of this type may include traversing conveyors, elevators, reels and various rotary tools. The relatively light weight of hydraulic motors should facilitiate movement of motors from one machine to another. If an hydraulic pump and motor combination is used on several implements, cost to the farmer may be very reasonable.

Fig. 2 illustrates a direct-mounted implement requiring rotary power from the tractor. If a slip-tube shaft connects the implement drive to the tractor power take-off, it must telescope to a retracted position when the implement is lifted. Often a shaft of suitable length when retracted is too short when the machine crosses a terrace and the shaft would separate unless suitable provision is made to prevent it. Stops can be used to limit downward motion of the implement relative to the tractor, but this results in unprocessed areas adjacent to terraces. A long shaft can be driven by a power-output location further forward on the tractor, but long telescoping shafts often become unbalanced and universal-joint and bearing life is seriously reduced. These problems are further aggravated if a shear pin is provided to

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1954, on a program arranged by the Power and Machinery Division, and published with the approval of the Director of the Pineapple Research Institute as Technical Paper No. 230.

(Left) Special pineapple plow with an hydraulic motor-driven conveyor-belt moldboard • *(Right)* A pineapple harvester which uses five hydraulic motors and two hydraulic rams, all controlled by a single operator. The speed of the five motors can be selectively modified, or they can be individually reversed by manipulating finger-tip controls

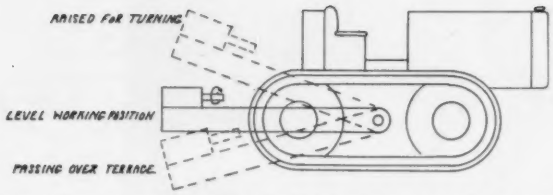

Fig. 2 Position variations of a direct-mounted power-driven farm tool

permit the tool to leave the soil without raising the hitch. An hydraulic motor provides a simple and satisfactory solution. A number of similar machines originally equipped with mechanical drives have been modified to employ hydraulic drives with excellent results. Hydraulic motors are available with power ratings in excess of that produced by the largest tractor, and size is thus not a limiting factor.

A second type of installation in use on product-harvesting machines involves a conveyor which is located some distance above the power plant and the discharge end must move fore or aft, up or down and side to side, or any combination of these motions. A suitable mechanical-conveyor-drive arrangement is left to the imagination of the reader. It would be complex and expensive at best. On several machines the problem was solved easily and inexpensively with an hydraulic motor and control valve. Hydraulic equipment also was used to achieve the movements described.

Stepless variation of hydraulic-motor speed by use of flow-control valves is an asset which is frequently most desirable. Distributing conveyors can be adjusted to rate of material inflow. Processing machinery can be adjusted to density of the crop. Use of hydraulic motors permits the adjustment of speed of one element relative to another element without stopping to shift gears.

Mechanical drives frequently require overload clutches which are usually troublesome and require frequent adjustment. An hydraulic motor can be repeatedly stalled without damage when the hydraulic circuit is provided with a simple trouble-free relief valve. No reset of overload protection device is required, for as soon as the loading is reduced to design starting torque, operation recommences. Hydraulic motors can be readily reversed by operation of the control valve. This often facilitates backing out an overload of material being handled or processed and the operator can clear a stoppage without leaving his seat.

Hydraulic power is ideally suited to agricultural work, since the system is totally enclosed and is not endangered by wet or dusty conditions. The most common field maintenance requirements are the tightening of connections when leaks develop or replacement of improperly protected hoses which have been damaged. These repairs can be made by any farm hand with common wrenches. Rarely are other problems encountered when specifications on type of oil and frequency of filter servicing are adhered to. During three years of close association with one group of machines involving over 100,000 hr cumulative total hydraulic-motor operation, I did not have occasion to examine the inside of a single motor. Cumulative total hydraulic-motor operation in our industry has totaled in excess of two million hours and maintenance requirements have been negligible.

Manufacturers' catalogs usually contain ample information to guide in the selection of equipment, and application engineers are available for consultation. There are numerous

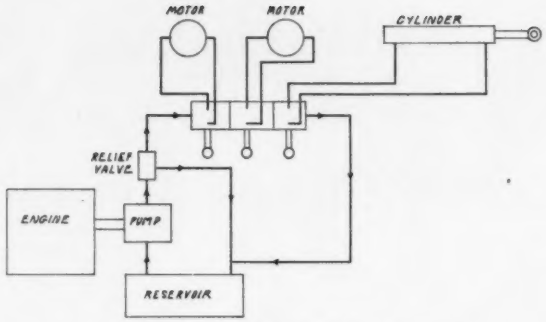

Fig. 3 A single-pump hydraulic circuit

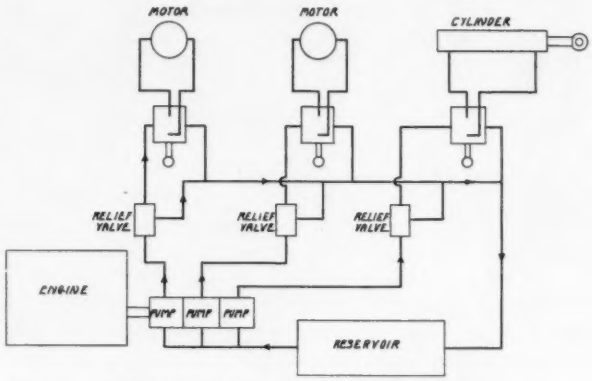

Fig. 4 A multiple-pump hydraulic circuit

special-purpose controls developed for air-craft and industrial applications which are often used in sequence and automatic control circuits, and for these, skilled maintenance personnel are required. Circuit designs for agricultural use should be simple, rugged and easily repaired. Cost and weight will be influenced by the system operating pressure selected. Early designs of hydraulic circuits on agricultural machinery were for operation at low pressures. Both cost and weight can be reduced by designs for higher pressures for which excellent, safe and reliable controls, motors, cylinders, hoses and hose connections are available. For example, motor A will develop 450 lb-in torque at 500 psi, and motor B will develop the same torque at 1125 psi; and the cost of B is 67 percent of A while the weight of B is 50 percent of A. Selections should be based on a tabulation of the cost and weight of items for a low-pressure system compared with a similar tabulation for a high-pressure system. Similarly, motor speed must be selected with consideration being given to initial costs, weights and power-transmission efficiencies. With equal system pressures, motor B operated at 1800 rpm will produce the same power as motor A at 800 rpm. Selections should be based on a tabulation of the cost and weight of motor and speed reducer compared with the cost and weight of the low-speed motor alone.

Hydraulic motors are reputed to be inefficient. Actually motors are usually very efficient but the hydraulic circuit they are used in may be extremely inefficient. A carefully designed hydraulic system will operate with power-transmission efficiencies as high as 85 percent, which compares favorably with most mechanical systems involving a number of components. The two circuits most frequently used are illustrated in Figs. 3 and 4. When power requirements are intermittent, the circuit shown in Fig. 3 is satisfactory. An open-

center control-valve bank is used to permit relief of pump loading when power is not required. That is, the pump circulates oil through the valve bank at a pressure only sufficient to overcome line friction. When one of the valves is engaged, line pressure and pump loading becomes that required to operate the motor or cylinder, or the pressure-relief setting, whichever is the lower. This circuit is ideal when only one power site will be in operation at a time and on an intermittent basis. If two valves are simultaneously operated, the major portion of the high-pressure oil will move to the site of lowest pressure requirement. To prevent "starving" the other site, a flow-regulating valve is often installed in the line of lower pressure requirement. This valve may also serve as a motor speed controller by regulation of volume of oil flowing to the motor. Flow dividers are also available to control rate of flow to separate elements and prevent starving.

The pump used in this circuit must be selected and driven to supply the maximum volume of oil required at any time. If one of the power sites is continuously operated, oil pumped in excess of this requirement must be vented through a pressure relief valve which of necessity must be set at the maximum pressure required by the system. This is of minor importance if the vented volume is small in comparison with the volume continuously used, and the relief valve setting is not much greater than system operating pressure. However, if intermittent requirements are large in comparison with continuous requirements, the system will be inefficient and excessive oil heating will result.

Fig. 4 illustrates a circuit which is better suited to systems having a variety of continuous and intermittent power requirements. This circuit provides in effect a number of hydraulic couplings, since each hydraulic motor is supplied by a separate pump. With this system, each pump loading pressure is automatically that required to operate the motor, up to the overload relief point. As loadings on the motor increase or decrease, back pressure or output pressure at the pump is automatically adjusted. This is ideal and a most efficient arrangement. If loadings in proportion to rating are approximately equal on two or more motors, they can be operated from a single pump, provided such loadings maintain a reasonably constant relationship and starving of one of the units will not occur. Flow dividers may be used to prevent this. Intermittent requirements are supplied by additional pumps on a basis which will produce similar efficiencies. The number of pumps which can be used is limited only by initial cost restrictions. Two or more pumps on a common shaft are available and any number of single or double pumps can be mounted on a power divider receiving power from a single engine shaft.

Separate pressure-relief valves have been shown in each of the illustrated circuits to emphasize their necessity. Often the relief valve can be obtained as an integral part of the pump or control valve. The first circuit is usually of lower initial cost than the second, and for certain applications it is well suited. However, for conditions of widely varying power requirements at a number of continuously operating power sites, and where efficiency is important, the second circuit is superior. Experience has shown that complex machines equipped with the first circuit operate with the main power plant fully loaded most of the time, while otherwise identical machines equipped with the second circuit operate with the main power plant loafing much of the time.

Hydraulic motors are often used in series, with the oil flowing through one motor to the second motor. This arrangement assures approximate synchronization despite fluctuation of oil pressure or volume. Such an arrangement on a synchronized system such as conveyor and elevator or feeder and processor is very desirable. When one motor is overloaded and stalls, the other also stops, thus avoiding serious jamming of material handled. Obviously the pump must supply oil at a pressure which is the sum of the two individual motor requirements.

One type of machine with several years of successful use employs seven hydraulic motors and five hydraulic rams. A single operator controls all of these. The speed of the seven motors can be selectively modified, or they can be individually reversed by manipulating finger-tip controls. Agricultural machines of this class have operated over 1000 hr per year with less than 5 percent of operating time lost to repairs and maintenance. Operators of farm machinery such as this can enjoy a standard of living equal to that of industrial machinery operators. The farm machinery industry has a real challenge to increase the output of farm workers and maintain their standard of living on par with that of the industrial worker. This will require machines of greater power, designed for greater output, yet using a single operator who must control a number of operations with speed and precision. Design of these machines will inevitably lead to problems which will provide excellent opportunities for use of hydraulic motors.

The 22 J. I. Case self-propelled combines are shown in a mammoth rice-harvesting operation in Cuba

Hydroponics—A Challenge for Engineers

J. Sholto Douglas

FROM time to time during the last twenty years reports have been published about extraordinary crop yields obtained by the use of various methods of soilless cultivation of plants. Also known as hydroponics, a word derived from Greek and meaning "water working", as opposed to geoponics or agriculture, "care of the earth", techniques of this nature have made considerable progress. Large-scale installations are being operated today in places as far apart as India, Australia, Japan, and Great Britain. In the United States, much work has also been carried out, and many market gardeners and truck farmers employ soilless culture to produce first-class crops.

All this is, of course, of great interest to agricultural engineers, especially as hydroponics may yet revolutionize horticulture, and effect profound social and economic changes in the life of the nation. By divorcing crop production from the soil, and opening up ways of making towns, urban areas, and barren or desert regions self-supporting in foodstuffs, soilless cultivation promises to bring about a number of alterations in growers' machinery demands. Many new types of equipment will, in the not so far off future, be called for. Problems of town crop production, and installation of hydroponicums on high rooftops or in barren places, will require solution. Water conservation, and distillation, will become more important than soil conservation.

The rapid advances of soilless cultivation lately have been due to the simplification of the practical culture techniques effected in Bengal. A new method has been evolved there, which may be easily adapted and modified for other countries. Until recently several difficulties always arose to confront any ordinary person anxious to produce vegetables and flowers by hydroponic means. First there was the question of apparatus and equipment; complicated mixtures of nutrient salts had to be prepared for which tanks, electric time clocks, and waterproof troughs were necessary. Secondly, the operator was required to possess a considerable amount of technical knowledge. Finally, plant deficiency symptoms had not been properly interpreted and no reliable diagnostic guide existed.

Fortunately research workers continued to study the various problems still awaiting solution, especially in India. At the government experimental station in the Darjeeling district of Bengal, trials were begun in 1946. A new system which is inexpensive to install, easy to maintain, and economical to operate is now being practiced successfully in many parts of the world. Although originally designed for tropical or subtropical conditions this method can be modified for use in temperate zones.

Plants are grown in troughs constructed from almost anything, except galvanized iron, which, if used, needs first coating with asphalt emulsion: and filled to a depth of 8 in with a coarse mineral aggregate, preferably a mixture of about five parts of gravel, rock chippings, or leached cinders, of ⅜ to ¼-in grade, and two parts of sand. Concrete, alkali puddled clay, or mud plaster, as well as wood and asbestos, are all suitable material for hydroponic beds. The plant nutrients, in the form of a compound of fertilizer salts, or as synthetic resins—amberlites—are applied dry in a stipulated ratio to the area of the trough at regular intervals. They are afterwards watered in. For the convenience of the non-technical operator, chemicals are obtainable in packeted or tablet form. The aggregate or growing medium in the troughs must be kept moist enough to allow unchecked development, like a damp sponge just lightly wrung out. Excessive wetness must be avoided, for it would kill the plants by waterlogging the root crowns. Plants need good aeration at all times. The main chemicals which should be supplied to crops growing in a hydroponicum include sodium nitrate, potash, magnesium and calcium sulphates, and a phosphate. Several hundred different mixtures may be utilized. In practice the soilless culturist would merely submit all details of the proposed layout to the nearest institution specializing in hydroponics. A properly balanced formula, the prescription of which would have been made up by experts would then

(Continued on page 170)

Paper prepared expressly for AGRICULTURAL ENGINEERING.

The author—J. SHOLTO DOUGLAS—is a specialist in the soilless cultivation of plants at the Agricultural Institute of West Bengal, India.

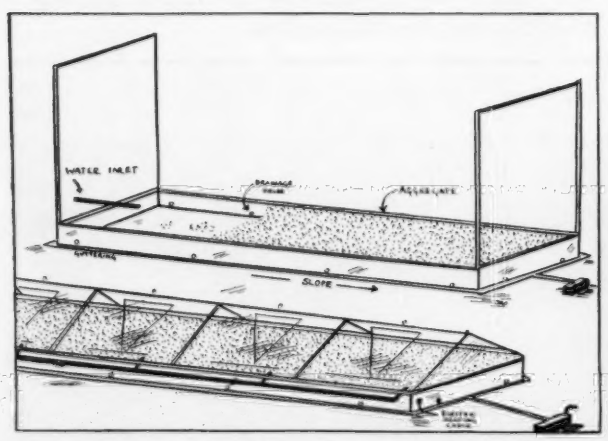

Fig. 1 Troughs used for hydroponic cultivation in connection with simplified Bengal methods

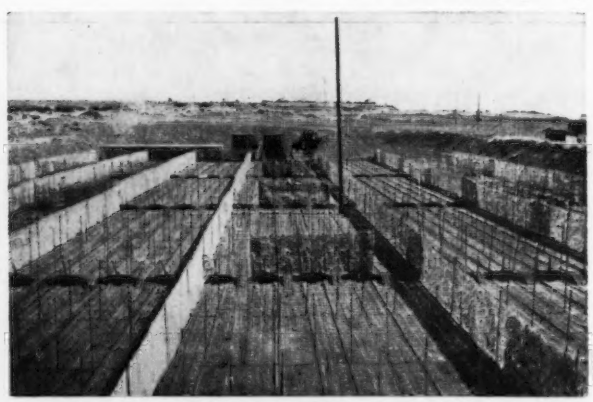

Fig. 2 U.S. Army hydroponicum on Iwo Jima. (Reproduced by permission of Reinhold Publishing Corp.)

Status of Hay Crusher Development

H. D. Bruhn
Member ASAE

A report of extensive experimental tests conducted on crushing equipment, as well as on crushing procedures, to observe the effect of various factors on the drying rate of forage crops

FOR many years the University of Wisconsin, through its various departments in the college of agriculture, has been interested in developing a grassland type of farming particularly suited to dairy production in the temperate climate of the state This interest in grassland farming has been reflected in the University's agricultural engineering department by two decades of research on machinery and equipment adapated to harvesting and curing forage crops. In the curing of high-quality forage, proper drying of the crop has been an important consideration because Wisconsin weather, particularly humid in the early period of hay harvesting, makes it difficult to field cure completely this early luxuriant forage without some rain or dew damage. Research in the use of forced air and artificial heat in mow and wagon drying of the forage has brought about a reduction in the period of time between field cutting and mow storage to such an extent that haymaking often can be a one-day operation with subsequent lessening of the chance of moisture damage.

The particular subject of this paper is our study of forage crushing. The research took this line of attack in our efforts to dry forage artificially without the shattering and loss of plant leaves caused by excessive leaf drying in our attempts to reduce the moisture content of heavier, ranker plant stems. In other words, it was hoped that some process of crushing and cracking the stems would bring about a more uniform and faster field drying of leaves and stems.

A search of the literature revealed that early development work with forage crushers was conducted in California during the early 1930's with a machine designed by E. B. Cushman (1, 2, 3)* in cooperation with the Food Machinery Corporation, San Jose, Calif. The early machine was a self-propelled unit and consisted of a cutter bar and draper similar to a grain binder platform with a set of crushing rolls fed by the platform draper. The machine was equipped with a spreader to redistribute the crushed material on the ground. Later the machine was redesigned with the crushing rolls parallel to the cutter bar and of essentially the same length. Corrugated rubber-covered steel rollers were used on the early machine, and it was equipped with rotating brushes to keep the rolls clean. The later machine was equipped with one smooth rubber-covered roll and one smooth steel roll.

Subsequent experimental work at the Illinois (4), Mississippi (5), Missouri (6), and Kansas (7) agricultural experiment stations was carried on with crushers, which picked the forage out of a swath and crushed it, and also with combination mower-crushers. These machines varied considerably in detail, some being engine driven and some driven by tractor power take-off.

Later experimental work was carried on with commercially available or experimental machines at Michigan (8) and Pennsylvania (9). During the course of our experimental work there appeared reports from Mississippi (10, 11) and Ontario (12).

In the summer of 1947 our laboratory (13, 14) constructed an experimental forage crusher with which we hoped *(a)* to determine the factors affecting the increased drying rate of crushed forage reported by previous investigators, *(b)* to study the application of forage crushing to Wisconsin conditions, and *(c)* to alleviate many of the functional and mechanical difficulties of the early machines. This investigation to date has covered seven years with the resultant data and conclusions reported in this paper.

EXPERIMENTAL

Experimental work with forage crushers at many experiment stations has consistently shown that crushing forage crops accelerates the drying rate. The magnitude of the acceleration, however, varies considerably which has led to some misunderstanding as to the value of crushing forage.

Over the past years at the Wisconsin experiment station, we have run a great many tests on crushing equipment and crushing procedures to study the effect of various factors on the drying rate of forage.

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1954, on a program arranged by the Power and Machinery Division.

The author—H. D. BRUHN—is professor of agricultural engineering, University of Wisconsin.

* Numbers in parentheses refer to the appended bibliography.

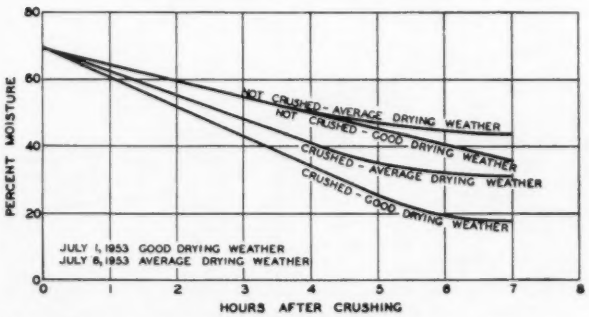
PERCENT MOISTURE
HOURS AFTER CRUSHING
NOT CRUSHED - AVERAGE DRYING WEATHER
NOT CRUSHED - GOOD DRYING WEATHER
CRUSHED - AVERAGE DRYING WEATHER
CRUSHED - GOOD DRYING WEATHER
JULY 1, 1953 GOOD DRYING WEATHER
JULY 8, 1953 AVERAGE DRYING WEATHER

Fig. 1 Effect of weather conditions on the comparative drying rates of crushed and uncrushed alfalfa

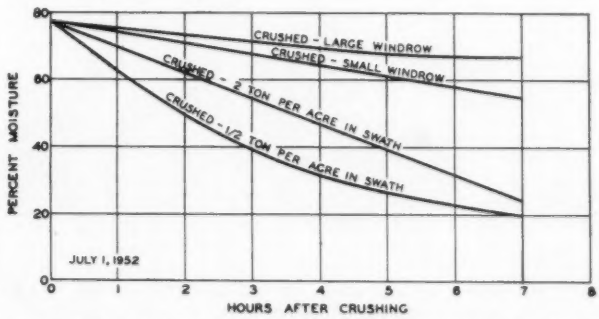
PERCENT MOISTURE
HOURS AFTER CRUSHING
CRUSHED - LARGE WINDROW
CRUSHED - SMALL WINDROW
CRUSHED - 1 TON PER ACRE IN SWATH
CRUSHED - 1/2 TON PER ACRE IN SWATH
JULY 1, 1952

Fig. 2 Effect of density of the crop and windrowing on the drying rate of crushed alfalfa and clover

Included in this paper are curves indicating the drying rates of forage after various crushing treatments. These curves were prepared from individual tests and are so indicated by the day on which the data was taken. In each case, however, tests have been repeated a number of times and the curve presented was selected because it seemed to most nearly represent the results obtained from all the tests to determine the effect of any one factor on the drying rate.

Equipment Used and Sampling Procedure Followed

In the early work on forage crushing at Wisconsin one commercial machine and one experimental machine were used. With this equipment it was possible to study the comparative drying rate of crushed and uncrushed material. On a field basis it was necessary to take a great many samples and average the results to get a fair index of the moisture content at a given time.

The early experimental machine was later replaced with a second experimental machine constructed similarly to a combine or forage harvester with a cutter bar. With this machine the forage was cut, and, as it fell, it dropped on a conveyor which carried it top forward to the feeding and crushing rolls. This PTO-driven machine and the tractor with which it was used provided three different ground speeds at a given PTO speed. It also provided at each ground speed two different roll speeds. The roll pressure could be quickly changed and it could be readily adjusted so as to have either one or two sets of rolls operating.

The crushing rolls were readily interchangeable. Both 8½-in smooth rolls and corrugated rolls were used. To avoid confusion, all the tests reported in this paper were conducted with the 8½-in diam smooth rolls. The rolls were 36 in long, and the width of cut of the machine was 60 in.

The term speed ratio as used in this paper refers to the ratio of the product of the peripheral velocity and the length of the roll as compared with the product of the rate of travel and the width of cut.

To facilitate conducting more tests with a greater degree of accuracy, the common procedure of collecting many field samples and determining the moisture content of each was discarded, and a set of 2-in-deep sample pans, 3 x 4 ft in dimension, with screen bottoms, was constructed. A given quantity of crushed or uncrushed forage would be quickly collected on each sample pan at the discharge of the crushing machine. The sample could be quickly weighed, excess material removed to obtain the weight of sample desired, and the samples set out to dry on the ground where the standing crop had just been removed to simulate normal drying conditions. The sample could be raised at one-hour intervals, weighed on a portable hanging scale, and immediately set back in its original position to continue drying. At the end of the test drying period the total sample was oven-dried to determine the total dry matter weight. The initial moisture content and moisture content at any weighing time could then be calculated. Following this procedure our data were quite consistent, and usually tests could be duplicated with a fair degree of accuracy.

The time required to set up nine samples from different crushing treatments and an uncrushed check sample seldom required more than 30 min, or about 3 min per sample. The tests were usually set up between 8:00 a.m. and 9:00 a.m. depending on the dew conditions of the night before.

Effect of Weather Conditions on Drying Rate

The effect of weather conditions on the increase of drying rate that can be obtained by crushing alfalfa is clearly shown in Fig. 1. July 1, 1953, was a good drying day, and at the end of five hours of drying time the crushed sample had dropped to about 25 percent moisture and was ready for storage. The uncrushed sample was still near 45 percent and could not have been hauled until late the next day. On the following July 6 the crop was still essentially the same and the crusher was set exactly the same. However, at the end of the five-hour period with just an average Wisconsin drying day, the crushed sample had only dropped to a moisture content about 13 percent lower than the uncrushed sample dried the same day. This indicates very clearly that the greatest gains in drying rate are experienced when drying conditions are very good, and the advantage of crushing diminished gradually with poorer drying conditions until the point is reached where neither crushed nor uncrushed forage dries.

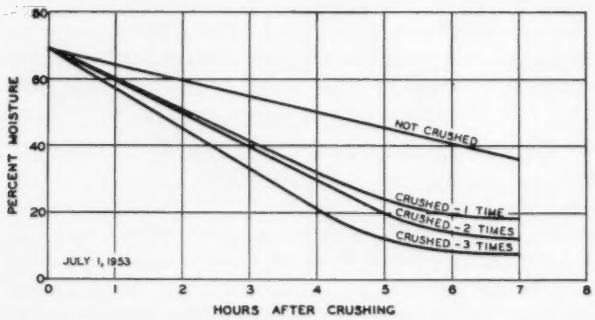

Fig. 3 How crushing alfalfa one, two, and three times through a single pair of rolls affects the drying rate

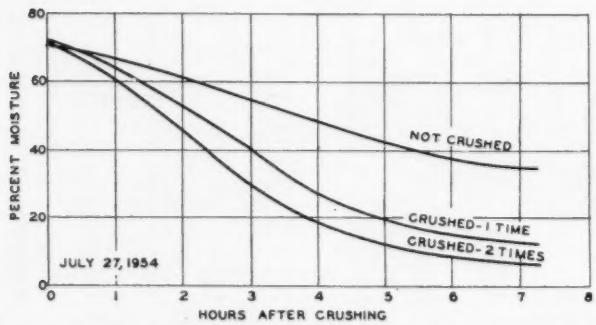

Fig. 4 How crushing alfalfa one and two times with a forage crusher equipped with a double set of rolls affects the drying rate

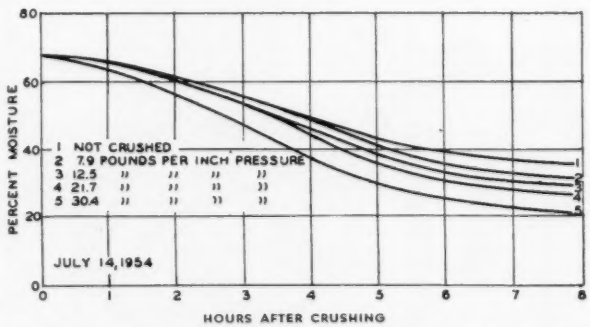

Fig. 5 Effect of roll pressure of a forage crusher on the drying rate of crushed mature alfalfa and clover

Effect of Windrowing on Drying Rate

It is frequently suggested to us in Wisconsin that we windrow forage at the time it is cut and cure it in the windrows. On the basis of the drying rate, the folly of such a procedure is shown in Fig. 2. The drying rates of four crushed samples are shown here. The initial moisture content of the crop was rather high, the day was just average from a drying standpoint, and the condition of the ground was rather wet.

The swath sample in which the density was the equivalent of one-half ton of dry hay to the acre dried quite rapidly. Two tons to the acre in the swath dried fairly well. However, when the density was the equivalent of a 7-ft swath of a two-ton crop rolled into a 3-ft windrow, the drying rate was too low to be practical. In a double windrow the drying rate was so low that the forage surely would spoil before drying. Whether it were crushed or uncrushed wouldn't make any appreciable difference in the windrow drying rate. Therefore, windrowing of crushed forage immediately after crushing will mask out any appreciable good that can come from crushing, and crushing factors affecting the degree of crushing can not be evaluated by this method.

Effect on Drying Rate of Multiple Passes of Forage

If running forage through a set of crushing rolls once increases the drying rate, one wonders what effect repeating this treatment will have on the drying rate. The comparative results of crushing one, two, and three times are shown in Fig. 3, These tests were conducted on a good drying day, and as a result multiple crushing showed up to considerable advantage.

To prepare the material which was crushed two and three times, we picked up the forage which went through the machine once and put it through a second and third time by hand. Hand feeding is usually slower than the normal machine rate and, as a result, produces a more effective crushing. The alfalfa and clover stems in the three-times crushed forage were quite shredded, and the resultant material had a lighter green over-all color, although there did not seem to be appreciable clipping of small stems and leaves. In these tests the roll speed ratio was not high, and the roll pressure was about 30 lb per in of roll length.

A crusher was equipped with two sets of crushing rolls (Fig. 8) and second-crop alfalfa was fed from one set directly into the second set running at 80 percent of the speed of the first. The effect on drying rate is shown in Fig. 4. The roll pressure was 30 lbs. per lineal inch of roll, and the roll speed to ground speed ratio was 3.44 to 1. The forage fed once through the machine with two sets of rolls had dropped to 25 percent moisture in a little over four hours, and that which made an additional pass through the two sets of crushing rolls dropped to 25 percent moisture in about 3½ hr. Either crushing treatment gave ample time in one day to dry the forage sufficiently and to haul it into storage. The uncrushed forage was not ready for storage until well into the second day.

Effect of Roll Pressure on Drying Rate

Up to a certain point roll pressure very definitely affects the drying rate unless other factors mask out the pressure effect. This is shown in Fig. 5 where the drying rate of uncrushed, first-crop alfalfa and clover, mixed, is compared with the same crop crushed at roll pressures of 7.9, 12.5, 21.7, and 30.4 lb per lineal inch of roll length. Both sets of rolls operated at the same speed with a surface speed to ground speed ratio of 3.44 to 1. The higher pressure definitely is shown to produce the most effective crushing. Due to the maturity of the crop the increase in drying rate due to crushing did not seem to be as great as could be expected. There was a noticeable quantity of dry leaves knocked from the stems which probably could be attributed to the overmaturity of the crop on which this particular data was collected.

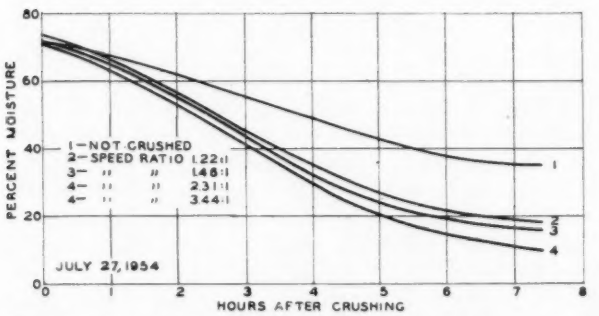

Fig. 6 Effect on the drying rate of the ratio of crushing-roll surface speed to ground speed

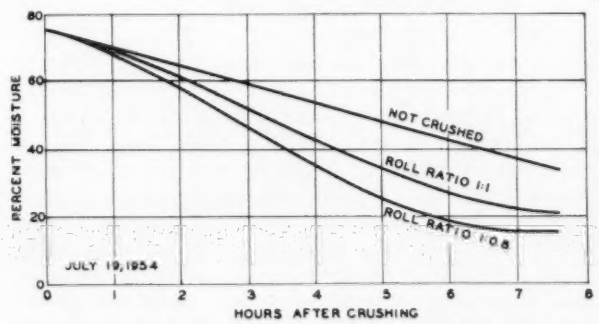

Fig. 7 Effect of relative roll speed in a multiple-roll crusher on the drying rate of crushed alfalfa. The 1:1 ratio indicates that both pair of crushing rolls run at the same speed. The 1:0.8 ratio indicates that the second pair of rolls is running at eight-tenths of the speed of the first pair

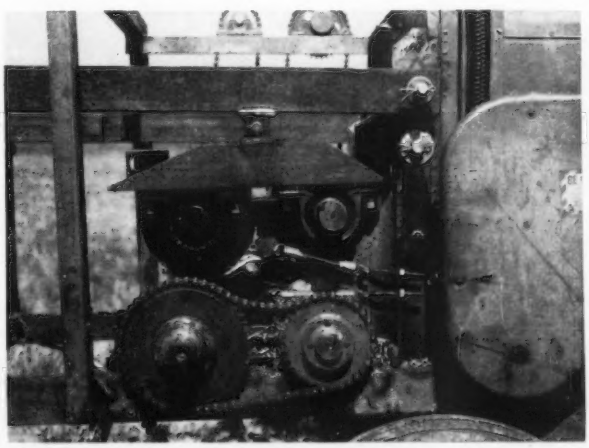

Fig. 8 The forage moves from right to left as it passes through between the two pairs of crushing rolls. The second pair of rolls is chain driven from the first pair which makes it possible to vary the relative speeds easily. A large sweet clover stem is shown doubling over and spreading out as it passes from the faster turning rolls to the slower rolls

Analysis of Crushing Roll Feeding Charactertistics (Fig. 9)

D = the diameter of the crushing roll

d = the stem diameter

μ = the friction factor between roll surface and material being crushed

P = the force exerted on the individual stem

T_e = the pressure set up by spring tension on the rolls

ϕ = the crushing angle and also the feeding angle

$P \cos \phi = T_e$, $P = T_e / \cos \phi$

Tangent force
$= \mu P$
$= \mu T_e / \cos \phi$

Feeding force
$= \mu P \cos \phi$
$= (\mu T_e / \cos \phi) \cos \phi$
$= \mu T_e$

Resisting force
$= P \sin \phi$
$= (T_e / \cos \phi) \sin \phi$
$= T_e \tan \phi$

To feed properly
$\mu T_e > T_e \tan \phi$
$\mu > \tan \phi$

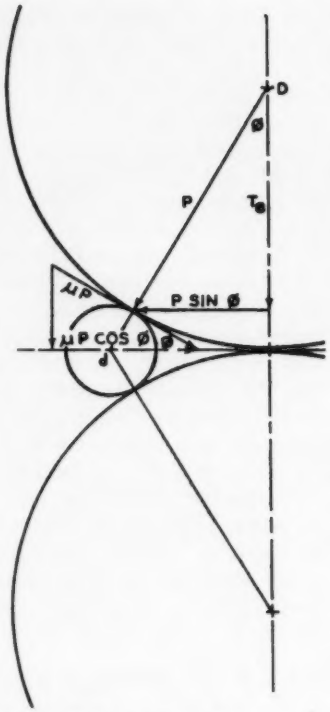

Fig. 9 This graph provides an analysis of the feeding characteristics of the crushing roll

Effect of Roll Speed on Drying Rate

In our work it has been more difficult to obtain consistent results on the effect of the roll surface to ground speed ratio than on any other factor. The curves shown in Fig. 6 indicate the drying rate of samples crushed at four different speed ratios compared with uncrushed material. There seems to be a definite trend toward higher drying rates at the higher speed ratios. However, the drying rates of the two samples at the higher speed ratios were so nearly alike that one curve could truly represent both drying rates.

Comparable series of tests were repeated many times, and the trend consistently pointed toward the desirability of higher speed ratios; however, almost invariably there would be one erratic sample which would not fall into the pattern. The only plausible explanation seems to be that a slight bunching on the feeder platform of our experimental machine may be responsible for heavier or lighter than average feeding rate which may be of greater magnitude than the variation in feeding rate brought about by the different speed ratios.

When two sets of crushing rolls are used and the material feeds directly from one set to the next, both sets of rolls can run at the same speed or the second set can run somewhat slower than the first set. A comparison of the drying rates obtained is shown in Fig. 7. With the second set running slower, the moisture content drops to the 25 percent level over one hour earlier than if the two sets of rolls run at the same speed. This more effective crushing probably is due to the opening up, twisting, and rearranging of the stems as they pass from one set of rolls to the other (Fig. 8).

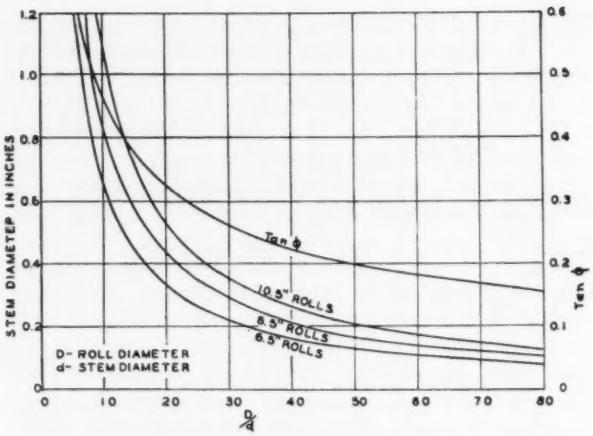

Fig. 10 Correlation of the friction factor, tan ϕ, and the maximum size stem that can be expected to feed satisfactorily through a given size pair of crushing rolls

Feeding Characteristics

One very disagreeable feature of a forage crusher is the clogging of the crushing rolls by large-stemmed weeds which occasionally, instead of entering the crushing rolls tip first, come to the rolls crosswise. If these weeds are carried on a mat of small-stemmed forage, they will be pulled through the rolls. If, however, there happens to be a break in the uniform feeding of the forage so that a large weed comes to the bare rolls, it will not pull through and will prevent additional forage from entering the rolls. Special unclogging devices are of limited help in a situation such as this, but the fact remains that serious bunching, poor crushing, and lost time are the results of this clogging. Some operaters prefer to operate with a lower roll-surface speed to ground speed ratio in badly weed infested fields. The normal thicker mat of forage that results from the lower speed ratio seems to carry the large weeds through the rolls better than a thin layer of forage with occasional blank spots.

It has been observed that crushers built with a feed table and conveyor or draper tend to clog less than crushers with spring-finger-type pickup devices. The conveyor tends to feed the large weeds tip first while the spring fingers tend to feed them crosswise.

The diameters of the crushing rolls have a definite bearing on the feeding characteristics of a crusher. The mathematical analysis and the section of crushing rolls comprising Fig. 9 show this relationship.

The correlation of tan ϕ to the ratio of the roll diameter to the stem diameter is shown graphically in Fig. 10. The maximum diameter stem that will feed satisfactorily through a set of crushing rolls is determined as follows: Assume a friction factor of 0.3 which is probably high. Start at the 0.3 point on the tan ϕ scale on the right of the chart; proceed to the left on the 0.3 line until the tan ϕ curve is reached; then drop vertically downward until the desired roll diameter curve is reached; and then proceed horizontally to the left and read from the left-hand scale the maximum stem diameter that can be expected to feed through the rolls if the stem happens to meet the rolls crosswise. Thus for the 0.3 friction factor the D/d ratio would be 23 and the maximum size stem that could be expected to feed through 10.5-in rolls would be 0.46-in diameter. The 8.5-in

rolls would take 0.38-in stems, while the 6.5-in diameter rolls would give trouble with any stems over 0.29-in in diameter.

Another difficulty encountered in feeding results from bunching of the forage. Bunching may result from faulty mower operation or from poor design in the pickup or conveying portion of the crusher. Crushers, on which the roll pressure is controlled by long springs, feed bunches better than those on which the rolls are controlled by short springs which cause the roll pressure to increase rapidly as the rolls separate.

Clipping and Stripping of Leaves and Stems

We have observed that under certain conditions forage crushing may bring about clipping and stripping of small stems and leaves from the main plant stem. This leaf and stem clipping may result when the forage is accelerated suddenly as it moves through the machine or when various units of the feeding and crushing mechanism are operated at different speeds. Clipping may also result from a combination of excessive crushing pressure at high roll to ground speed ratios or from repeated crushing at high pressure and low rates of feeding.

Clipping and stripping are rather difficult to evaluate; however, samples of alfalfa were photographed after various crushing treatments to indicate the seriousness of the situation under some conditions (Figs. 11 to 14).

CONCLUSIONS

There are several factors in crushing-roll design and operation which contribute to effective crushing and subsequent fast drying. High roll pressure, high roll speed, multiple rolls, operating the second set of rolls slower than the first set, and feeding the material to be crushed to the rolls in a very thin uniform layer all contribute toward more effective crushing and higher drying rates.

Because of excessive damage to the crop in the form of stripping of leaves or clipping small stems which may result from abnormally high pressure, high roll speed, or irregular feeding, it appears that an attempt should not be

Fig. 11 *(Upper left)* This alfalfa was cut with a hand scythe, was not crushed, and is shown in its original state • Fig. 12 *(Upper right)* Alfalfa making one pass through the crusher with two sets of crushing rolls suffers comparatively little clipping, yet dried quite rapidly. This appears to be a desirable procedure. Pressures and speeds were the same as the one-time crushed sample shown in Fig. 4 and the number 4 curve in Fig. 6 • Fig. 13 *(Lower left)* The alfalfa shown in this picture was run through only one set of rolls under a spring pressure of 48.4 lb per in of length. Crushing at this higher pressure resulted in a drying rate quite comparable to that recorded for forage crushed with two set of rolls at the lower pressure under which that in Fig. 12 was crushed. Clipping was not serious although some was noticeable • Fig. 14 *(Lower right)* Crushing alfalfa once in the normal manner with one set of rolls under high pressure as shown in Fig. 13, and then recrushing by hand feeding again at high pressure resulted in the badly stripped and clipped sample shown. Such a procedure results in a terrifically high drying rate, but is primarily of academic interest only and has little practical value because too high a percentage of a crop crushed in this manner could not be picked up from the field after it had dried

made to obtain a high drying rate by carrying one factor to extremes, but rather each factor should be so controlled that the sum of the effect of the individual factors should bring about the maximum desired drying rate with only very limited leaf losses.

Two pair of crushing rolls operating at moderate speed, pressure, and rate of feeding produce a drying effect comparable to one pair of rolls operating at high pressure, high speed, and low rate of feeding. However, the two pair do less damage to the crop in the way of clipping and stripping than the one pair when operated for high performance. Operating the second pair of crushing rolls slightly slower than the first pair seems to increase the effectiveness of the crushing with no apparent increase in the clipping and stripping.

Under normal Wisconsin climate and crop conditions windrowing forage crops immediately after cutting and crushing retards the drying and as a result tends to mask out the advantage of the most effective crushing procedures. Limited work tends to indicate the drying rate of mature alfalfa and clover are not accelerated as much by crushing as are these crops when in the early bloom stage.

When a machine is constructed and operated in such a manner as to take the fullest practical advantage of all of these factors, the drying rate of the crushed material will primarily be limited by drying conditions, and if this be the case, then altering to a limited extent one factor of operation may have little effect on the drying rate unless drying conditions are considerably above average.

There are many ways to treat a forage crop to obtain a much higher drying rate than can be obtained with the normal crop in the swath, but only those treatments are practical which leave the crop in such condition that a high percentage of it can be picked up by harvesting equipment after curing.

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Hydroponics—Challenge for Engineers

(Continued from page 164)

be given to him. Books on the subject have been issued, and full advice is available from the Hydroponic Information Centre Post Box 31, Bombay, India, which has been set up for the purpose of publicizing the new Bengal methods of soilless culture, on behalf of the Indian authorities.

The yields of crops under hydroponic cultivation have been increased remarkably. Over 20 lb of tomatoes per plant, and 200 tons to the acre have been produced in Bengal. Soilless cultured maize gave 6,000 lb of grain per acre. Other advantages include reduction in growing area, freedom from soil diseases, no weeding, or hard manual labor. There is much quicker growth, no dirt and no smells. Vitamin content is equal to soil-grown plants; in fact crops of high mineral content may be raised at will. Flavour is first-class. Costs are 30 percent cheaper than in soil.

By means of hydroponics, millions of tons of good greenstuff could be grown on town rooftops, along roadsides, in deserts, or at barren sites. Apart from the 80 acres of United States Army hydroponicum in Japan, there are large beds now working at many other localities. India is producing various crops by soilless culture. In Great Britain, it has taken hold in greenhouses and nurseries, especially among the important carnation growing industry. Before another five years have elapsed, hydroponics will be a very important force in the agricultural world.

Harvesting and Storing High-Moisture Wheat

Summary of a progress report by H. T. Hurst, W. H. Johnson, I. P. Blauser and G. W. McCuen, agricultural engineering department, Ohio Agricultural Experiment Station presented at the ASAE annual meeting at Minneapolis, Minn., June, 1954

THE study reported was devoted to the reduction of field and harvesting losses and preservation of grain quality. Grain quality was determined by (1) U.S. grade, of which test weight in pounds per bushel has been the controlling factor, (2) germination and (3) milling and baking tests.

In 1953 and 1954 soft red winter wheat was combined at moisture contents of 14 to 28 percent moisture content and dried with natural air and heated forced air up to 160 F, varying from 2.5 to 42 cfm per bu. Efforts were made in 1954 to establish the air-flow requirements for preserving grain quality when combined at various moisture contents and dried with forced air at temperatures of 160 F, 100 F, and natural.

In terms of test weight and germination, the grain quality was not preserved when combined above 22 percent moisture content in 1953, and above 18 percent in 1954, even with air flows of 42 cfm per bu. But in terms of milling and baking tests, quality was preserved in grain combined at 28 percent moisture or below and dried with 10 cfm per bu. There are indications that considerably less than 10 cfm per bu will suffice if the grain is combined below 20 percent moisture.

Potential grain quality in terms of test weight decreased at an average rate of 1 lb per bu every four days from 30 percent moisture content until after the normal combine season. Milling and baking tests on these 1953 samples showed no significant change in quality. At the same time, field shatter losses mounted at an increasing rate which totaled 5 to 7 percent by July 20.

Controlled-Atmosphere Storage

I. J. Pflug and D. H. Dewey
Member ASAE

THE CA (controlled-atmosphere) storage of fruits and vegetables has an important place in the food-marketing system since the storage life of some products can be considerably lengthened. At the present time, the use of the CA storage in quantity is limited to apples; however, experimental work is being carried on with the hope that in the not too distant future the CA technique can be applied to other fruits, vegetables and florist stocks.

The CA fruit storage is a refrigerated storage where the atmosphere surrounding the fruit is maintained at a level other than the normal 21 percent oxygen, 0.03 percent carbon dioxide and 79 percent nitrogen. In the CA storage, the respiration process of the fruit reduces the oxygen level and increases the carbon dioxide level. The decrease in oxygen and increase in carbon dioxide both tend to slow down the rate of respiration and extend the storage life of the fruit. The CA storage was developed in England where the first commercial CA storage (7)* was constructed in 1929. England now has over 4,000,000 bu of storage capacity. The CA storage capacity in the United States is estimated to be about 500,000 bu, all located in the Northeast.

Before a product can be commercially stored under CA conditions the individual variety of fruit or vegetable must be tested to find the specific level of oxygen and carbon dioxide that will give the desired extension of storage life without bringing on a physiological disorder. Fruits and vegetables that are susceptible to these disorders are not adaptable to CA storage. The reaction of a specific fruit to a given storage condition varies with the variety, and a variety grown in Michigan may react differently than the same variety grown in Iowa or New York. At the present time, most of the CA capacity is being used to store McIntosh apples. These apples, when stored under CA conditions of 3 per cent oxygen and 5 percent carbon dioxide at 38 F, may have twice the storage life of apples stored in air at 32 F.

Engineering Considerations in the Storage of Fruits and Vegetables by the Controlled-Atmosphere Technique

There are two types of CA storage. In one type, the sum of the concentrations of oxygen and carbon dioxide is always 21 per cent. The desired combination is maintained by ventilating the storage. In the second type of CA storage, the oxygen plus carbon dioxide is less than 21 per cent. The oxygen is maintained through controlled ventilation and carbon dioxide is removed by absorption. Sodium hydroxide (caustic soda) or calcium hydroxide may be used for absorbing the carbon dioxide. An Orsat-type gas analyzer is used to measure the oxygen and carbon dioxide levels of the storage.

Fundamental data for the design of controlled-atmosphere storages are exceedingly meager considering the large number of storages that are operating successfully. The chief recommendation in the construction of the CA storage is that it be as tight as economically possible. It is unfortunate that the increased value of the product stored is not sufficient to warrant construction of truly hermetic rooms and that we must be content with rooms that are reasonably tight. Further study of the physical aspects of the problem should make it possible to ascertain in advance the relative degree of tightness necessary for a room to operate satisfactorily.

Little knowledge has been accumulated on the physical operating characteristics of CA storages in the United States. Pflug and Southwick (2) found that a breather bag speeded up the rate at which some rooms acquired the desired atmosphere. They also found that sealed rooms develop pressure cycles accompanying the temperature cycle of the room. Kidd, *et al* (1) concluded that in practice the main cause of leakage was the mass movement of the atmosphere into and out of the storage and not the escape of carbon dioxide by diffusion. Pflug and Southwick (2) arrived at similar conclusions.

The present-day CA storage can be described as being tight when compared to a refrigerated storage, but not hermetic. Pflug and Southwick (2) outlined a method of measuring the rate of leakage as a function of the differential pressure. Air will flow through the holes in a non-hermetic

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1954, on a program arranged by the Committee on Agricultural Processing. Authorized for publication as Journal Paper 1715 of the Michigan Agricultural Experiment Station.

The authors—I. J. PFLUG and D. H. DEWEY—are, respectively, members of the agricultural engineering and horticulture departments, Michigan State College.

*Numbers in parentheses refer to the appended bibliography.

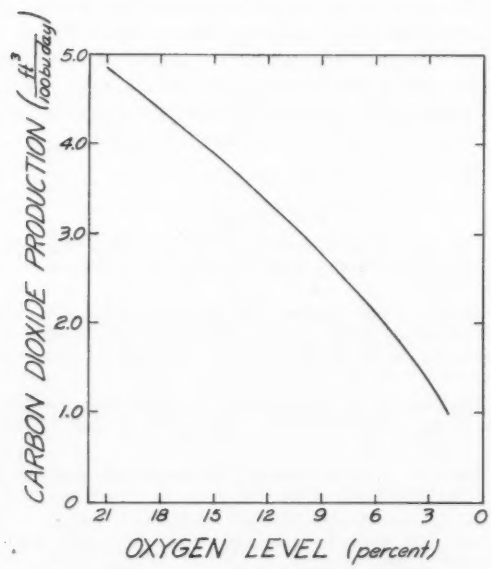

Fig. 1 Carbon dioxide production of McIntosh apples at 38 F as a function of oxygen level from data presented by VanDoren (6) and Phillips and Poapst (3)

room whenever there is a pressure gradient. The rate of flow will be proportional to the differential pressure across the holes. The room is subject to pressure differentials arising from five sources: *(a)* changes in atmospheric pressure, *(b)* external air movements, *(c)* temperature changes in the storage, *(d)* air movement in the storage, and *(e)* the absorption or removal of gas from the storage.

It is important to consider the physiological characteristics of the stored fruit in the design of the storage since it is living and slowly carrying on respiration. Chemically the respiration process involves intercellular combining of oyxgen with stored sugars to produce water, carbon dioxide and heat.

Fig. 1 illustrates the relation of carbon dioxide production with oxygen level for McIntosh apples at 38 F. This graph was based on data from Van Doren (6) and Phillips and Poapst (3). According to these and other data, the rate of oxygen drop for a hermetic room with a given volume of total atmosphere per bushel of fruit can be determined. In Fig. 2 oxygen-reduction curves for different volumes of atmosphere per bushel are illustrated. The volume of atmosphere per bushel will be higher in the small than in the large storage and will be higher in a palletized storage than in a storage that is hand loaded. An incompletely filled storage will have a higher volume of air per bushel than a filled storage.

The data in Fig. 2 are a starting point in determining the necessary degree of tightness of the storage. The net decrease in oxygen per day for a non-hermetic storage will be the difference between the oxygen consumed in respiration and the oxygen gained through leakage. The effect of each agent causing pressure differentials must be evaluated individually. Methods and procedures that will eliminate or reduce leakage from these agents should be used where possible.

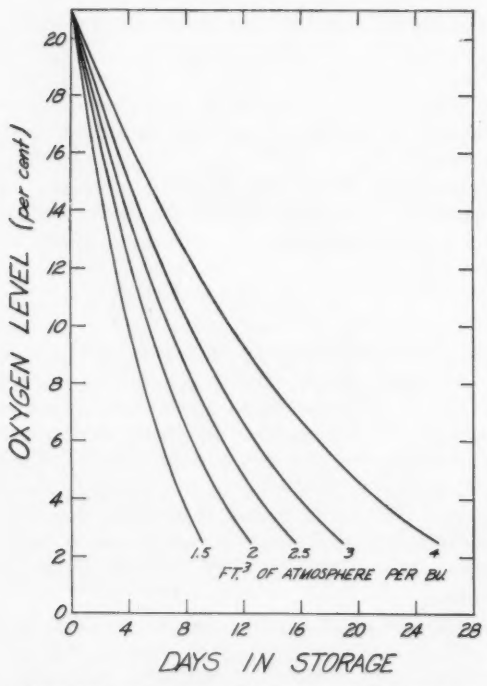

Fig. 2 Theoretical rate of oxygen reduction of McIntosh apples in a hermetic CA storage as affected by the volume of atmosphere (cubic feet) per bushel of fruit

Changes in atmospheric pressure will cause air to move into the storage as the barometer rises and out of the storage as the barometer falls. The regular cycling of the barometer may cause leaks to develop if an expansion device is not used. Pflug and Southwick (2) found that the oxygen gain from atmospheric pressure fluctuations was small compared to the leakage from other causes. Leakage from atmospheric pressure fluctuations can be approximated from weather data. The average leakage due to external air movement will be negligible, but could reach significant proportions during times of high wind. The overall effect of wind will be to create areas of positive pressure on the windward side of the building and a vacuum on the leeward side.

Temperature changes in the storage will cause the specific volume of the air in the storeroom to change. A vacuum will be formed when the temperature decreases while a positive pressure will be developed with increasing temperatures. These specific volume changes will occur whenever an off-on temperature-control system is used and the amount of leakage will be proportional, within limits, to the heat gain of the refrigerator. Since the leakage pattern due to temperature fluctuation is a cycle of great amplitude and short duration, its effect can be somewhat reduced with a breather bag. The circulation of air in the room by fans or blowers will cause pressure variations within the room. Little is known about the magnitude of these pressures in actual controlled-atmosphere storages. Sainsbury and Gerhardt (4) found a vacuum of 0.5 to 1.5 in of water near the fan inlet of some refrigerated storages. Leakage can be expected to increase with increased air velocities inside the room.

The removal of carbon dioxide or other gases by absorption will cause air to leak into the room until the volume of gas removed has been replaced. A substantial vacuum may develop in a tight room if provision has not been made for replacing the removed atmophere. The oxygen gain of a room due to the absorption of carbon dioxide will be approximately 21 per cent of the carbon dioxide removed.

The development of a sound design procedure would eliminate many of the present hazards of CA storage. The cold storage of fruits and vegetables, at best, involves considerable economic risk and this is greatly increased when controlled atmospheres are utilized. The assurance of satisfactory mechanical operation of CA rooms would be helpful in justifying the additional construction and operation costs of storage of this type.

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Water Cooling for Livestock in Hot Climates

C. F. Kelly, T. E. Bond and N. R. Ittner
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THE comfort of livestock, their rate of growth, and the efficiency of their use of feed are all affected by the thermal environment. Adverse effects are more pronounced from hot environments than from cold environments. This has been shown in various studies—with dairy cattle at the state universities of Missouri (1)* and California (2), with swine at the University of California (3), with poultry at the Beltsville (USDA) Research Center (4), and with beef cattle at the Imperial Valley Field Station (5). All of these investigations have shown that the depressive effects of heat begin to be felt at a relatively low temperature level—around 75 F.

The 75 F isotherm in Fig. 1 divides the country into two parts: All the area south of the line has an *average* temperature above 75 F during July, which is the hottest month in all parts of the country, except along the Pacific Coast, where August is hotter. The region south of the isotherm contains 51 percent of all the beef cattle (including calves) and dairy cattle (including heifers over two years old) of this country (6). Their 1953 value on farm and ranch was over 7⅕ billion dollars, out of a total value for the country of 16⅘ billion dollars.

Any method of offsetting or preventing the depressive effects of heat will certainly benefit the livestock producer.

Over a period of several years, in studies of ways to protect beef cattle from the extremely high temperatures found in the Imperial Valley of southern California, a number of factors were varied and tested: shade materials (7, 8), ground covers, and cooling devices that employ water. Water is an ideal cooling agent: it usually is cheap and abundant, and can be economically transported to the animals; it is non-corrosive and non-toxic; it has the highest heat capacity of any of the common liquids (1 Btu per lb F), and also the highest latent heat of evaporation (1050 Btu per lb at 70 F). This paper discusses tests, conducted over the period 1947-1954, that used water as a cooling agent in four different ways: *(a)* spraying the animals, *(b)* cooling the air, *(c)* cooling the shade surfaces, and *(d)* cooling the drinking water.

Evaluating Results

In investigations of this type, results are usually evaluated by observing the effects of the treatments upon physiological reactions of the animals—body temperatures, respiration rates, pulse rates, etc. But in these tests, involving range and feeder cattle, loose in a corral and largely unused to handling, obtaining physiological reactions without exciting the animals was difficult. A more significant evaluation to the agricultural engineer and to the producer is the efficiency of the use of feed. This method has been used for evaluating the four types of cooling methods tested. Control animals were maintained under conditions that were identical, except lacking the water treatment. Feeding trials were conducted for 60 to 90-day periods during the hottest part of the summer. An attempt was made to explain the results of each test in terms of the heat transfers involved.

Results from five years of experimental tests under hot weather conditions uniformly favor cooled drinking water as a cooling agent for beef cattle

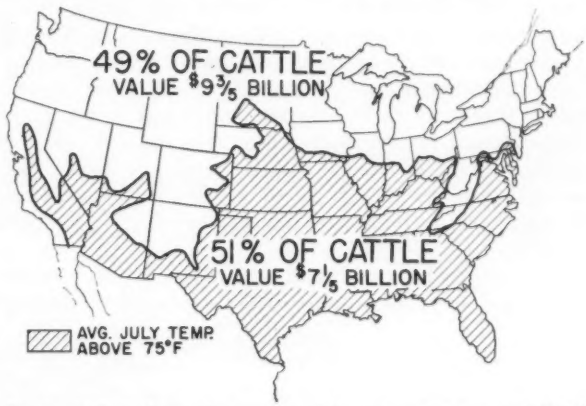

Fig. 1 75 F isotherm for average July air temperature in United States, and number and value of livestock in areas north and south of isotherm (6). (Isotherm from Climate and Man, USDA Yearbook, 1941)

Weather of Imperial Valley

Methods of cooling cattle that are found to be adequate during the extremely warm summer months in the Imperial Valley would prove practical and be of benefit in a large

TABLE 1. WEATHER DURING FEEDING PERIODS

Data for Imperial Valley Field Station during test periods, 1947 to 1954 inclusive

Year	Period of feeding trial	Air temperature (F)			Air relative humidity (%)			
		Average maximum	Average minimum	Mean	Average maximum	Average minimum	Noon	Mean
1947	July 23 to Sept. 15	105.7	74.7	90.2	67	26	34	46
1948	July 28 to Sept. 20	108.1	74.7	91.4	55	17	25	33
1949	July 12 to Sept. 16	104.3	73.4	88.9	71	24	31	44
1950	June 21 to Sept. 9	105.1	74.8	89.9	76	28	39	47
1951	July 3 to Sept. 27	103.7	71.8	87.7	78	29	36	50
1952	July 2 to Sept. 11	106.7	77.7	91.8	66	26	26	40
1953	June 30 to Sept. 22	105.5	77.1	91.3	61	19	24	36
1954	June 24 to Sept. 16	103.6	76.4	90.0	67	19	28	39

* The mean relative humidity is the average of all 2-hr readings throughout the period.

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1954, on a program arranged by the Farm Structures Division.

The authors—C. F. KELLY, T. E. BOND, and N. R. ITTNER—are, respectively, associate agricultural engineer, California Agricultural Experiment Station (Davis); agricultural engineer, Agricultural Engineering Research Branch, U.S. Department of Agriculture, and specialist in animal husbandry, Imperial Valley Field Station, University of California.

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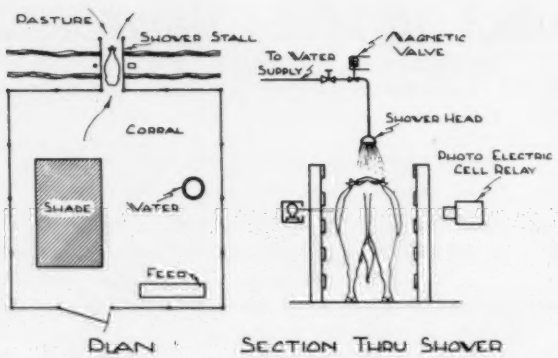

Fig. 2 Single shower head controlled by photoelectric cell relay. Plan shows relation between shower stall, shade, and pasture. Section indicates position of relay with respect to shower stall and animal

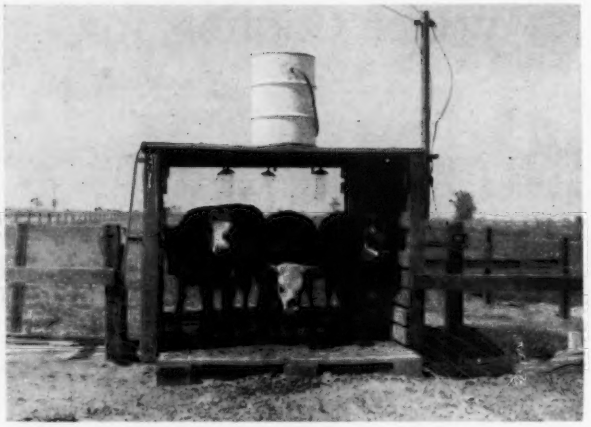

Fig. 3 Shower stall, located over irrigation ditch, in use in tests of 1950. Water flow is controlled by photoelectric cell relay

part of the United States. The average minimum temperature was seldom below 75 F during the summer feeding periods, extending from about July 1 to September 15. The average maximum temperature for the entire season was always above 103 F. Each summer of the tests had 8 or 10 days in which the maximum temperature reached 115 F or above, with a high of 123 F recorded in July 1949. The absolute humidity, though not so excessive as in some parts of the country, is high, especially in August, when the prevailing winds shift from west to southeast, bringing in humid air from the Gulf of Lower California.

The average maximum, minimum, and mean air temperatures and relative humidities for the season are shown for 1947-1954 in Table 1.

Spraying the Animals

European breeds of beef cattle, lacking sweat glands, are not cooled by evaporation of sweat. However, Kibler and Brody (9) have shown that at temperatures above 75 F dairy cattle that lack sweat glands nevertheless lost about two-thirds of their insensible (latent) heat of metabolism through the skin, and only one-third by way of the lungs. This evaporative cooling of the body was not sufficient to prevent discomfort when the environmental temperature was above the critical range of 75 to 85 F. Surface temperatures of the animals were about 105 F when the environmental temperature was 105 F, which indicates that all heat above this temperature level must have been dissipated through evaporation.

Spraying dairy cattle with water has been investigated by Seath and Miller, in Louisiana (10). The effect of wallows and rain on water buffalo, zebu cattle, and sheep was studied in India by Minett (11). In 1946, Ittner (12) conducted preliminary studies with dairy cattle in the Imperial Valley. He found that, at air temperatures of about 109 F and relative humidities of 18 percent, spraying the cows reduced body temperatures about 1.5 F and slowed respiration rates by about 20 breaths per minute.

The spray tests reported herein were conducted each summer, from 1947 to 1952 inclusive, except for 1948. The results are summarized in

TABLE 2. NUMBERS OF ANIMALS, BREEDS, INITIAL WEIGHTS, GAINS, AND FEED CONSUMPTION

Summary of tests with four water cooling methods at Imperial Valley Field Station, 1947 to 1954

	Year	Length of feed trial	Number of cattle	Breed	Average initial weight	Average daily gains	Increase of test animals over check	Feed consumption
		(Days)			(lb)	(lb)	(lb)	(lb/100 lb gain)
SPRAYING ANIMALS								
Test Animals	1947	---	3	Hereford	(1)			
Check Animals			None					
Test Animals (2)	1949	66	8	Hereford	643	1.57	0.37	
Check Animals			8	Hereford	628	1.20		
Test Animals	1950	80	4	(3)	851	1.45	0.22	572 (4)
Check Animals			4	(3)	831	1.23		668
Test Animals	1951	86	5	Shorthorn	827	1.64	0.06	1335 (5)
Check Animals			4	Shorthorn	846	1.58		1370
Test Animals	1952	71	10	Herefords	765	0.94	0.16	2221
Check Animals			10	Herefords	768	0.78		2481
COOLING AIR								
Test Animals	1948	54	7	(6)	428 (7)	1.05 (7)	0.36 (7)	1158 (8)
Check Animals			7	(6)	430 (7)	0.69 (7)		1230 (8)
COOLING SHADE SURFACES								
Test Animals (9)	1948	54	8	(11)	429 (7)	0.90	0.21 (7)	1266 (8)
Test Animals (10)			7	(6)	420 (7)	0.89	0.20 (7)	1091 (8)
Check Animals			7	(6)	430 (7)	0.69		1230 (8)
COOLING DRINKING WATER								
Test Animals	1950	83	4	Herefords	849	1.46	0.39	1618
Check Animals			4	Herefords	833	1.07		2092
Test Animals	1951	86	5	Shorthorns	839	1.56	-0.02	1366
Check Animals			4	Shorthorns	846	1.58		1370
Test Animals	1952	71	10	Herefords	761	1.04	.26	1958
Check Animals			10	Herefords	768	.78		2481
Test Animals) Hay	1953	84	7	Herefords	867	1.51	.33	1395
Check Animals)			7	Herefords	868	1.18		1694
Test Animals) Grain	1953	84	6	Herefords	881	2.01	.44	1073
Check Animals)			7	Herefords	869	1.57		1279
Test Animals) No	1954	84	7	Herefords	815	1.70	.19	1030
Check Animals) Salt			7	Herefords	815	1.51		1157
Test Animals) Salt	1954	84	7	Herefords	811	1.50	.03	1258
Check Animals)			7	Herefords	817	1.47		1233

(1) No weight observations
(2) Test cattle were in wire corral, check animals in board corral
(3) One purebred Hereford and 3 Hereford-Shorthorn crosses
(4) Plus pasture
(5) Cattle were on a grain ration: Rolled barley 20%; dried beet pulp 15%; alfalfa hay 60%; and barley hay 5%
(6) 5 Herefords and 2 Braffords
(7) Excluding the Braffords
(8) Includes Braffords; feed not weighed separately
(9) Burlap sub-roof
(10) Galvanized iron sub-roof
(11) 6 Herefords and 2 Braffords

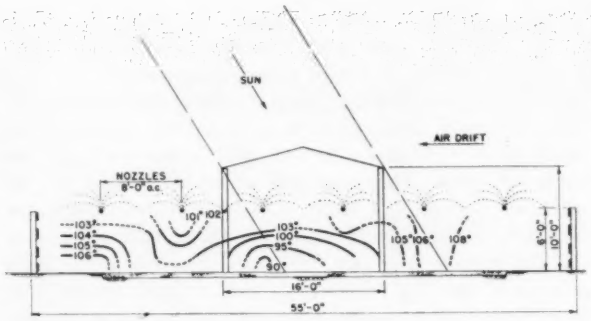

Fig. 4 Arrangement of fogger nozzles under 16 x 24-ft shade in tests of 1952. Air Temperature isotherms are for September 8, 1952, at 1:15 p.m., when outside temperature was 109 F

Table 2, together with the number and breed of animals and their initial weights. Water temperature at the nozzles varied from 85 to 95 F in all the tests.

Following are brief descriptions of the studies, by year:

In 1947 three Hereford heifers were housed under a 16 x 24-ft aluminum shade equipped with three shower heads giving a fine spray. The spray heads were 8 ft above the ground. Water pressure at the heads was 30 lb per sq in. A concrete slab under the shade carried the waste water to a drain. The animals made little use of the sprays, got only the ends of the hairs wet (not their skins), and did not seem to be getting any measurable benefits. One spray head—with the hole enlarged to ⅛ in to wet the animals to the skin—was then lowered to 6 ft above the ground, cutting down the drift. When the animals were also wetted down with a hose several times, to show them the benefits of standing under the shower, they began to make greater use of the sprays. By the end of the summer one animal was standing under the shower about three hours per day. Occasionally, even though the shadow movement left the showering animal exposed to the sun, it nevertheless stood under the shower even when the air temperature was 109 F.

Wetted animals usually had body temperatures 2 or 3 deg. lower than those of dry animals, and lower respiration rates by twenty or more breaths per minute. These animals never used the sprays at night, even when night temperatures did not go below 80 F. They preferred standing in the open, exposed to the cooler sky. The continuous operation of the showers used excessive amounts of water and created unsanitary conditions under the shade, even though the floor was concrete.

In 1949 (there were no spray tests in 1948) an inexpensive photoelectric cell relay ($30) and an electric solenoid water valve were used to control the water flow to a single coarse shower head (Fig. 2), to operate the shower only when an animal entered the stall. The shower was installed over an irrigation ditch so that waste water went directly into the ditch. The shower, with standing room for only one animal, was situated between shade and irrigated alfalfa pasture. It was anticipated that the cattle would wet themselves at frequent intervals when passing to and from the pasture and thus increase grazing time.

Several of the 8 test cattle (Table 2) used the shower very little, partly because they never learned its comfort and partly because "boss" cows would not let them into the stall. In spite of this the average daily gain of the test pen during

Fig. 5 Whirling-brush fogger device installed under shade in 1952 test. Note that animals all face away from fogger

the 66-day feeding period was 0.37 lb per animal greater than the gain of the unsprayed, check cattle.

In 1950 the shower stall was widened to 6 ft, three shower heads installed, and the number of test animals reduced to four, so that all would have equal opportunity to shower. All animals used the spray a great deal of the time

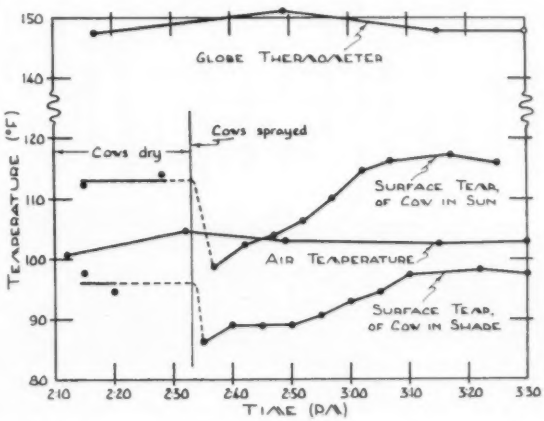

Fig. 6 Surface temperature of Brown Swiss cow in sun and cow in shade, before and after wetting, with air temperature and globe thermometer temperature in sun

during the days. They received all the alfalfa and barley hay they wanted but made little use of the pasture. They seemed to enjoy the water and to be definitely more comfortable than the unshowered check animals. The average daily gain per animal during the 80-day feeding trial was 0.22 lb greater

Fig. 7 Three-sided 16 x 24-ft shade cooled with 2500-cfm evaporative air cooler installed on south end. North end is open

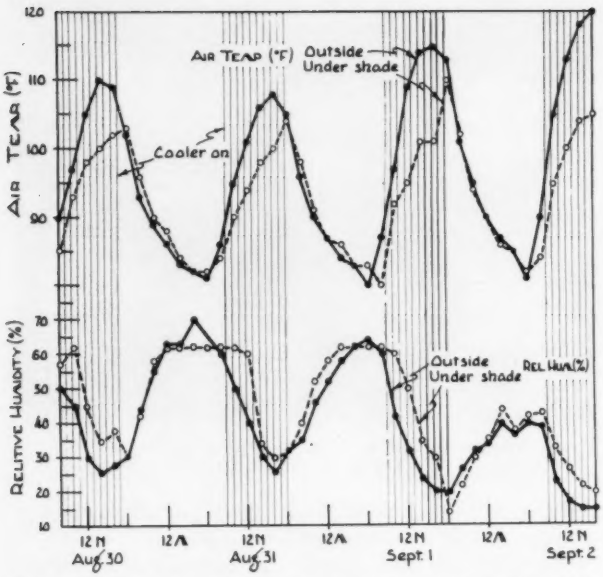

Fig. 8 Air Temperature and relative humidity outside and inside of 3-sided shade cooled with "desert" cooler in 1948. Vertical grid indicates periods of fan operation. Recording instruments were located at center of shade, 3 ft above ground

than the gain of the check animals (Table 2). Because of a shortage of irrigation water the showers were not operated during three or four days of each month. A view of the shower stall in operation is shown is Fig. 3.

In 1951 a test of very fine mist sprays was conducted in a feeding trial with five Shorthorns (2 steers, 3 heifers).

Fig. 9 Shades with surfaces cooled by evaporation of water used in 1948 tests. Shade on left has burlap subroof, shade on right galvanized-iron subroof

These spray nozzles, known as "foggers," have been used with some success in California to prevent the death of laying hens confined in cages during hot weather (Wilson (13)). Although mists had not been successful in 1947, it was thought that the extremely fine mist produced by these nozzles might prove more efficient in cooling, simplify the spraying equipment, cut down amount of water needed, and increase sanitation under the shade. Monarch No. H-61 nozzles were used, delivering 1 gal of water per hour under a pressure of 20 lb per sq in (manufacturer's rating) .

Six nozzles, 6 ft above ground, were arranged under the same 16 x 24-ft shade used in 1948, in two rows of three nozzles each. Nozzles were 8 ft apart in the rows, and the rows 7 ft apart. They were 6 ft above the ground, out of reach of the animals backs. The concrete slab was enlarged by 3 ft all around to improve the sanitary conditions.

The average daily gain was good for both test and check animals (Table 2) but the "fogged" animals gained only 0.06 lb per day per animal more than did the check animals, which was not significant. However, the feed consumption per 100 lb of gain was slightly less with the fogged group. The animals under the foggers appeared uncomfortable, and particularly avoided getting their heads in the mist. Their hair was seldom wetted enough to be plastered down to their skins. In fact, the beads of moisture sometimes appeared to cause the long hair to stand out from the skin, thus actually increasing insulation against heat transfer from skin to air.

The grain-and-hay-fed test animals seemed to suffer more from the heat than did animals on the Field Station that received only hay and pasture. This suggested that the grain ration might have masked possible benefits from the fogging.

In 1952, therefore, fogging was tried again, with hay the only ration. The number of nozzles was increased to 18, and the concrete slab again increased, to 30 x 40 ft. The arrangement of nozzles, shade, and slab is shown in Fig. 4, along with air temperature and relative humidity observations made at 1:15 p. m. on September 8, 1952. Some of the nozzles were always in shadow.

Ten Herefords were used for the feeding trial, with ten similar animals in an unfogged corral as checks. All twenty had their drinking water cooled to 65 F. (See discussion below on cooling drinking water.) Time of spray operation was as before: from about 8 a.m. until 4 to 5 p.m.

The sprayed animals showed a gain over the unsprayed cattle of 0.16 lb per animal per day (Table 2).

During the same summer a short trial (not a feeding experiment) was made with a commercial mechanical "fogger"—a whirling wire brush (driven by a ¾-hp motor) that dispersed atomized water from its periphery by centrifugal force (Fig. 5). Droplet size could be adjusted by varying the rate of water flow. When droplet size appeared about the same as that produced by the fogger nozzles, the air temperature was lowered from 110 to 95 F as far as 10 ft from the wheel. The animals were not wetted appreciably and avoided getting their heads in the mist clouds, but they seemed to like the lowering of the air temperature and the air movement induced by the rapidly whirling brush.

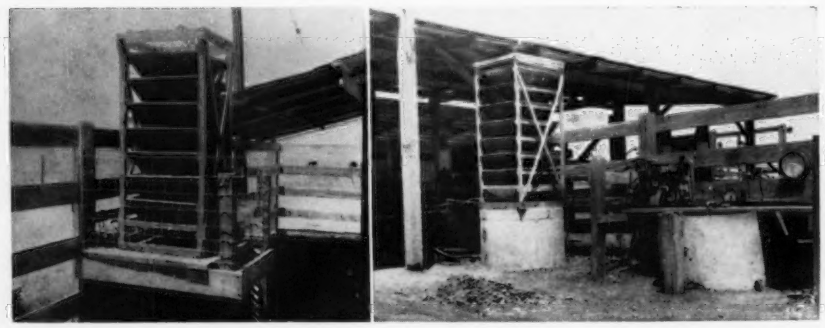

Fig. 10 *(Left)* Small evaporative cooling tower used for lowering temperature of drinking water in 1951 • Fig. 11 *(Right)* Mechanical refrigeration equipment and controls used for cooling drinking water in 1952 to 1954. The tower is for cooling condenser water

TABLE 3. WATER CONSUMPTION AND HEAT TRANSFERRED

Comparison of consumption of cooled and uncooled water, and cooling effects calculated

Year	Av. daily water consumption per animal		Av. temp. of uncooled water (F)	Daily difference in cooling effect per animal (1) (Btu)
	Water cooled to 65F (gal)	Uncooled water (gal)		
1950	15.4	16.6	88.2	2831
1952	12.3	15.0	89.6	2348
1953 – Hay ration	13.6	— (2)	89.2	—
– Grain ration	11.3	13.0	89.2	2084
1954 – No salt	12.6	14.1	86.3 (3)	2030
– Salt	20.3	19.5	86.3 (3)	3718

(1) Based upon raising daily consumption of water of the two different temperatures up to estimated body temperature of 103F
(2) Water quantity not measured
(3) Unshaded first month of test, then shaded

The cooling effect of sprays on animals is due to several different mechanisms:

- Wetting the animal to the skin produces cooling by conduction when water temperature is lower than skin temperature, with the amount of this temperature difference and the rate of water flow determining the amount of cooling.
- Further cooling will result from the evaporation of water that does not run off the animal. (This will be the greatest cooling if rate of water flow is curtailed by a limited water supply.) Part of the heat for evaporation will come directly from the animal by conduction, and part from sensible heat of the air. Cooling of air may or may not be of benefit, depending upon the opportunity the cooled air has of circulating back around the animal.
- The rate of heat loss from the animal surface (by convection, radiation, and evaporation) will vary directly with changes in the surface temperature of the animal due to wetting. As shown in Fig. 6, the animal-surface temperature may be expected to lower due to the evaporation of water. This can only decrease the rate of heat loss from the animal's surface by convection to the air, and by radiation to the surround. At higher environmental temperatures the direction of heat flow by these modes may actually be reversed, with heat flowing from the environment *into* the animal surface.
- The heat balance is further complicated by the animal's physiological reaction to a lowered skin temperature: Internal body heat flows toward the surface at an increased rate, by conduction through the body tissues and liquids. A lowered skin temperature will also change that part of heat transfer rate established by blood flow. In general the pulse rate of non-sweating animals is higher in a comfortable environment than in a hot environment (in contrast to man), but the literature is not clear as to the effect of artificial wetting upon blood flow.
- A number of cattle under one set of sprays will increase by evaporation the humidity already present from water droplets in the air. This may cause discomfort to adjacent animals by decreasing evaporation from their wetted surfaces. If the dry-bulb temperature of the air is above 85 F, this increased humidity will decrease heat loss from adjacent unwetted animals also, as recently shown with dairy cows by Thompson *et al* (14).

TABLE 4. ELECTRIC POWER CONSUMPTION

Year	Cooling method	No. of cattle treated	Electric power use		
			For season (kwh)	Per day (kwh)	Per animal-day (kwh)
1948	Cooling air (desert cooler)	7	88	1.63	.230
1951	Evaporative cooling tower	4	129	1.50	.370
1952	Refrigeration (drinking water)	20	1131	17.14	.857
1953	Refrigeration (drinking water)	13	786	9.36	.720
1954	Refrigeration (drinking water)	14	846	10.07	.718

Cooling Air by Evaporation

Animal heat loss can, of course, also be increased by lowering air temperature and increasing air velocity, thus increasing the fraction lost by convection. Cooling air by water evaporation is economical and feasible in hot, dry climates. Most commercial evaporative coolers pass air

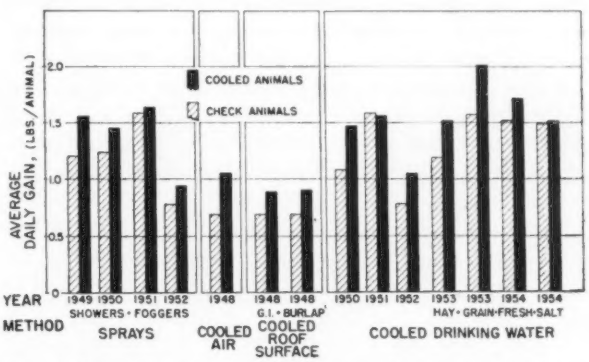

Fig. 12 Summary of average daily gains of both check and test animals in cooling tests at Imperial Valley Field Station, El Centro, from 1948 to 1954

through wetted excelsior pads. The sensible heat of air and unevaporated water is changed to latent heat of evaporation, thereby reducing the dry-bulb temperature of the air to a few degrees above the wet-bulb temperature. Gordon and Perry (15) have described application of the evaporative or "desert" cooler to the air conditioning of homes in California. Tavernetti (16) studied the cooling of poul-

TABLE 5. COSTS AND PROFITS

Estimated profit from cooling beef cattle in Imperial Valley by evaporative air cooler

Annual costs:		
Depreciation on $200 investment, 10%	$20.00	
Interest, 5% x ½ investment	5.00	
Maintenance, insurance and taxes, 5% x ½ investment	5.00	
Power, 88 kwh at $0.02	1.76*	
Total		$31.76*
Increased profits:		
Increased gain of 9 head; 0.36 lb. per day each, for 54-day feeding period, at $.25/lb.		43.74
Net profit		$11.98

* Does not include any demand charge
** Does not include any increased labor costs or charge for water

try houses by this means. Desert coolers applied to cooling beef cattle pose a special problem under California methods of management, for the structure must be open enough for free in-and-out movement of the cattle.

In 1948, an evaporative cooler was used under a 13 x 22-ft shade, with the area enclosed except for the north side (Fig. 7). The walls were of hay packed between woven-wire fencing nailed to both sides of 6 x 6-in posts. The roof was aluminum sheets laid over boards, with a 3-ft layer of hay supported on woven wire beneath it for additional insulation. An evaporation cooler with a rated capacity of 2500 cfm was installed under the south end of the shade, near the roof line. A conventional galvanized-iron shade, 16 x 24 ft and 10 ft high, was used as a check on performance.

The evaporator cooler, usually operated from 9 a.m. to 5 p.m., provided approximately one air change per minute. Continuous records were obtained for air temperatures and relative humidities, inside and outside (four hot days shown on Fig. 8). The dry-bulb temperature of the air at the fan outlet was reduced 15 to 20 deg by the cooler action to about 5 deg above the wet-bulb temperature of the outside air. However, since this cooled air quickly mixed with the warm air under the shade and received heat from the walls and cattle, the inside temperature was rarely as much as 10 deg cooler than the outside temperature, and never more than 10 deg cooler. It will be noted in Fig. 8 that the greatest reduction in air temperature occurred at the hottest time of the day.

Air motion within the shade induced by the fan increased heat loss by convection when the air temperature was below 102 to 105 F. (Above this temperature the surface temperature of a shaded animal may be below air temperature.) The air velocity was about 850 fpm at the fan outlet and 300 to 500 fpm at the shade center 3 ft above the ground. Near the shade walls and toward the open end it varied between 50 and 100 fpm. The cattle preferred standing where the air velocity was greatest, which of course was also the region of lowest air temperatures.

Ten Herefords and four Brafords† used in a 54-day feeding trial (July 28 to September 20) were divided into two groups equal in numbers and breed proportions: seven animals under shade constructed and cooled as described above, and seven under an uncooled galvanized-iron shade. They received all the good alfalfa hay they would eat, in mangers outside the shade. During the last 27 days they received daily one pound of rolled barley per head in addition. For the Herefords (429 lb average initial weight) average daily gain per animal was 1.05 lb under the cooled shade and 0.69 lb under the galvanized-iron shade, a difference of 0.36 lb which may be attributed to the cooler. The Brafords showed no significant difference in gains (Table 2).

The cattle, including the Brafords, entered the shade as soon as the cooler was started in the morning, leaving only occasionally, to eat and drink, usually between 1 and 2 p.m. About 4 p.m.—later on extremely hot days—the animals would leave the cooled shade and lie in its shadow, where they were exposed to the cool sky, for greater radiation heat loss.

†A Braford is a cross between a Hereford and a Brahman and is considered to be somewhat more heat-tolerant than a Hereford.

Cooling Shade Surfaces by Evaporation

Animals may lose heat to the surround, by radiation, as well as to the air, by convection and evaporation, when the radiosity of the surroundings is less than that of the animal's surface. Kelly *et al* (8) have shown how lowering the temperature of certain parts of the surround affects the radiation heat load on the animal.

In 1948, water was used to cool the surface of two shades in order to lower their temperature (by evaporation), which thereby lowered that portion of the radiant temperature of the surround. Both shades had double roofs, spaced about 3 ft apart. In the first shade, a subroof of burlap sacks was kept wet by four sprinklers spaced evenly above it. Surplus water dripped from the burlap to a drained concrete floor, usually wetting the cattle somewhat in the process. The burlap subroof (21 x 21 ft in size, compared with 16 x 24 ft for the upper aluminum roof) was 7 ft above the pavement (Fig. 9).

The second shade had a water-cooled subroof of galvanized iron (16 x 24 ft), sloping to one side to carry surplus water to a drain, leaving the floor dry. The upper roof was of hay and of the same size. The plain galvanized-iron shade mentioned previously was used as a check for these two cooled shades.

The water lowered the surface temperatures of both the burlap and galvanized-iron subroofs. When the air temperature was over 100 F, touch thermocouple measurements indicated average daytime (10 a.m. to 3 p.m.) reductions below air temperature of 19 deg for the wet burlap and 11 deg for the wet galavanized iron. At times, reductions below the temperature of the plain galvanized iron check shade were as much as 45 deg for the wet burlap and 35 deg for the wet galvanized iron.

All figures are for the portions of the lower roofs that were shaded. The subroof will not be completely shaded at all times unless the upper roof is considerably larger than the subroof. Observations were made to determine the comparative effects of wetting and shading on the temperature of galvanized iron. At 10 a.m., when the air temperature was 99 F, and the wind velocity below 2 miles per hour, adjacent parts of the galvanized-iron subroof had the following temperatures:

Treatment	Metal temperature
Dry, in sun	122 F
Dry, in shade	103
Wet, in sun	98
Wet, in shade	92

When shaded, the wet burlap subroof averaged 10 deg lower than when in the sun.

The wet pavement beneath the burlap-covered shade was as much as 10 deg lower than the ground below the check shade. The ground beneath the cooled galvanized-iron shade was 3 deg cooler than that under the check shade on the average, and 7 deg cooler during the hottest part of the day.

This lowering of the radiosity of the surround with shades has been reported elsewhere (8) to decrease the radiant-heat load on the animals from 176 Btu per hr per sq ft of animal surface with the uncooled check shade, to 165 with the wetted galvanized-iron shade, and to 157 with the wetted burlap shade. In other words, a 700-lb steer with a surface area of about 42 sq ft exposed to radiation would

receive 462 Btu per hr less under the wetted galvanized-iron shade than under uncooled surface shade, and 798 Btu per hr less under the wetted burlap shade. This calculation is based upon observations made at 11:30 a.m., September 1, 1948, when the ambient air temperature was 101 F.

Cooling the sub-roof had small effect upon air temperature: Beneath both cooled shades the air averaged about 2 deg cooler than outside. The check shade showed no lowering of air temperature.

Action of the two cooled shades was also evaluated by a 54-day feeding trial, checked against the plain galvanized-iron shade. Five check Herefords averaged daily gains of 0.69 lb each. Five Herefords (average initial weight, 492 lb) under the wet galvanized-iron shade each gained an average of 0.89 lb daily. Five Herefords (average initial weight, 429 lb) under the wet burlap shade each gained 0.90 lb per day each (excluding from the results a sixth animal, which was sick during most of the experiment). Most of the time these last animals were damp with drippings from the burlap, which undoubtedly contributed greatly to their comfort. But sanitation was a problem under these conditions: the concrete floor required cleaning several times a week.

Cooled Drinking Water

The methods of cooling beef cattle discussed so far have all depended directly or indirectly upon evaporative cooling effects. It was thought that cooling the drinking water might indirectly increase evaporative cooling by increasing water consumption, thus providing more water for loss through skin and lungs. At the same time there would be some direct cooling by transfer of body heat to the cool water in establishing a heat balance. Livestock drinking supplies in the Imperial Valley, mostly from irrigation ditches, may reach temperatures as high as 90 F in the ditch and 100 F in the drinking troughs. Experiments have been carried on with cooled drinking water for five years, 1950 through 1954 (Table 2).

In 1950, water was cooled to 65 F by a small direct-expansion cooler immersed in an insulated 200-gal concrete drinker. During the summer four Herefords each averaged 0.39 lb greater gain per day than similar animals receiving uncooled water of 88 F average temperature. All animals were fed good hay only, in dry lot.

In 1951, a small evaporative cooling tower (Fig. 10) was used to cool the water, in an attempt to lower costs over the mechanical refrigeration system. According to Perry (17), the performance of such towers depends upon tower design, wind velocity, water-circulation rate, and heat load. A well-designed tower will give a final water temperature within 5 deg of the wet-bulb temperature if wind velocity is as little as 1 mph. The tower constructed had eight 30 x 40-in trays, spaced 8 in apart, of ¼-in mesh hardware cloth. Water circulation was at the rate of 6 gpm. Water consumption of four animals was estimated as 60 gal per day. The heat load to cool this amount of water from 95 F down to 70 F was calculated to be 12,500 Btu. This was doubled, to allow for estimated reheating through the warming of the tank by radiation and convection. The resulting heat load of 25,000 Btu would have to be handled during the period when most of the water is drunk—about 9 hr during the daytime. The rule of thumb stating that 1 sq ft of screen area is needed for each 10 Btu to be dissipated per minute was then applied.

The average water temperature maintained by the tower for the 86-day summer feeding period was 75.4 F, an average cooling of around 9 deg—to about 3 deg. above the average daily wet-bulb temperature. The circulation pump was operated from 8 a.m. to 4 or 5 p.m.

In contrast with the results of the previous year, the five Shorthorns receiving this evaporatively cooled water gained no better than did the check animals (Table 2). Results may have been affected in this study by the following: The test animals were on full grain ration instead of the hay-only ration used the previous year, they came to the trial in unusually good condition, and the water was cooled only to about 75 F.

In 1952 the experiment was repeated, but with hay-only rations and mechanical refrigeration. The water was cooled to 65 F by a large mechanical, direct-expansion cooler (Fig. 11). Ten Herefords were put on a 71-day feeding trial, with ten similar Herefords receiving uncooled water as a check. The daily gains of the animals on the cooled water averaged 0.26 lb per animal over that of the check animals (Table 2).

In 1953 further clarification was sought concerning the relations between hay and grain rations and between warm and cold water. Four pens of 7 Herefords each were used, with cooled water (65 F) being supplied to one pair of pens, and uncooled water to the other pair. In one of each pair hay only was fed; in the other hay and grain were fed. The cooled water again proved effective. As for the hay-and-grain fed animals, the average daily gain of those on cooled water was 0.44 lb greater than that of animals on uncooled water; with hay-fed animals, cooled water produced 0.33 lb greater daily gain than did the uncooled water.

In 1954, salt was added to cattle rations to increase their intake of cooled water. All animals in all tests had, of course, free access to block salt in their corrals. In the previous experiments with cooled drinking water the animals consumed slightly less of the cooled than of the warm water (Table 3). The benefits noted above must have been due only to direct heat transfer from the animal to the cooled water taken in, and not at all to greater evaporative cooling through skin and lungs. The physiological relations involved have been discussed in detail elsewhere (18).

To make more water available for such cooling, an attempt was made to double the water intake of a group by the use of salt in their ration.‡ A salt-and-concentrate mixture is used extensively in range country to control the concentrate intake of animals self-fed on pasture. It has also been found greatly to increase animal water requirements (19).

Four groups of 7 Herefords each were confined in separate corrals and fed alfalfa hay and barley grain in pelleted form, plus a small amount of oat hay. Water in one pair of pens was cooled to 65 F; water in the other pair was uncooled. In one pen of each pair, excess salt in the amount of 1.7 lb per animal per day was given in the pelleted feed. Water consumption by the salt-fed animals did not double, but increased about 40 percent in the warm-water pens and

‡Studies with excess salt in the rations were in cooperation with J. H. Meyer, animal husbandry department, University of California (Davis).

60 percent in the cooled-water pens (Table 3). Nevertheless, no benefits could be ascribed to the salt. With salt-fed animals, the average daily gain of those on cooled water was 0.03 lb greater than that of animals on uncooled water; with animals receiving no salt, cooled water produced 0.19 greater daily gains than did uncooled water (Table 2).

Results from the five years tests were uniformly in favor of drinking water cooled to 65 F. For the period, the average superiority in daily gain per cooled-water animal was 0.32 lb, excluding the test of 1951 (when the evaporative cooling tower cooled the water only to 75.4 F) and the test of 1954 (when salt was used in the ration). As shown by the average rate of water consumption in Table 3, this superior weight increase cannot be due to increased water consumption, since actually the animals always drank less of the cooled water. Compared to the total metabolism of the animals, the cooling effect of cooled water was very small, never totaling more than 2831 Btu per animal per day (for unsalted animals)—about 4 percent of the average daily heat production (Table 3). Some physiological reason besides heat loss apparently must be credited for increased gains from drinking cooled water.

Economic Factors

The consumption of electric power by the refrigeration equipment was measured in the tests of 1952 to 1954, and was estimated quite closely from motor size and operation time for the air cooler and evaporative cooling towers used in 1948 and 1951 (Table 4). Cost of electrical energy is small for all of the methods; the equipment cost may be the deciding factor in selecting a method.

But comparative costs cannot be discussed without considering expected profits from increased weight gains. It must be remembered that rapidly gaining animals eat more (though not more per 100-lb weight increase, as shown in Table 2). Furthermore, extra labor will be needed to put almost any artificial cooling method into effect. Cost figures were not obtainable on all phases of the cooling methods, but as an example, an illustrative balancing of costs against increased income is here presented for cooling with a "desert" or evaporative cooler, as was done in 1948:

For the system as used, three walls must be added to a shade and a cooler constructed or purchased. Three low-cost 8-ft walls for a 13 x 22-ft shade are reasonably estimated at $100; the evaporative cooler (with ⅓-hp motor) cost $100. Depreciation, interest, taxes, etc., on the $200 total are calculated as suggested by Wooley (20), and power consumption is taken from Table 4, arriving at a total annual estimated cost of $31.76 (see individual items in Table 5).

On the income side of the ledger, an allowance of 32 sq ft space per animal permits nine to be accommodated under the shade. Animals in the 1948 tests of evaporative cooling benefited over check animals by average daily gains of 0.36 lb per animal per day throughout a 54-day feeding period. At 25¢ per lb the sale value of this increase for 9 animals is $43.74. Deducting the estimated cost of $31.76 yields a net profit of $11.98.

Costs for water, additional labor, and possible demand charges are not included in the above estimates, but for practical use on a farm the installation would be larger (lowering the investment cost per animal), the feed period would be considerably longer than 54 days (note the 81-day tests), and there would be some feed saving per *pound of gain.*

Similar estimates can be made of profit accruing from the use of cooled drinking water, sprays, or cooled shade surfaces.

Summary

Four methods of cooling cattle in hot climates with water were tested at the Imperial Valley Field Station, El Centro, California: *(a)* spraying the animals, *(b)* cooling air by evaporation, *(c)* cooling shade-surfaces by evaporation, and *(d)* cooling the drinking water. All methods were of some benefit in increasing weight gains of animals during hot weather. Comparison of rates of gain for cooled and uncooled animals is summarized in Fig. 12. In all cases where gain was increased, feed use per 100 lb gain was reduced (Table 2).

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Supplemental Irrigation of Pastures

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Experimental results indicate improved management practices are the key to making pasture irrigation profitable

RESULTS of six years of investigation of supplemental irrigation of ladino clover and grass pasture in southern Illinois are reported in this paper. The principal objective of the investigation was to determine plant growth and animal gains on irrigated pasture as compared with non-irrigated pasture. The work was also conducted to determine the effect of irrigation on available soil moisture, the most effective fertilizer treatment with irrigation, and the amount and frequency of water application.

Earlier observations (1)* showed that during the summer months soil moisture dropped to a point where many pasture plants died and the weed population increased. Productivity of pastures may drop during drought periods in July and August even in years that are not regarded as drought years. As a result, pasture productivity, and therefore animal-carrying capacity, becomes a limiting and uncertain factor in grassland farming.

Experimental Field

The field layout of the experimental project is shown in Fig. 1. The soil types are Grantsburg silt loam and Robbs silt loam. They are gray-brown with a brownish yellow or grayish yellow loam subsoil and compact, very slowly permeable, silty clay loam substrata. These soils are low in organic matter, and percolation is slow. The irrigated and non-irrigated fields are similar in slope, fertility, and soil-treatment history. Both were given applications of three tons of limestone and 1,000 lb of 32 percent rock phosphate per acre in the fall of 1947. Then they were seeded with a mixture of orchard grass, alta fescue, Kentucky bluegrass, redtop, and timothy. Ladino clover was broadcast over the fields in the spring of 1948.

Management

Sheep grazed the fields in 1948, sheep and beef cattle in 1949, and beef cattle in 1950, 1951, 1952, and 1953. Each five-acre field was pastured as a single unit, except in the 1953 season, when the fields were divided into seven grazing strips each. The strips were established in an attempt to improve pasture management by allowing a longer time for crop growth between irrigation and pasturing, and to require closer grazing and less tramping of the forage. Animal weights were recorded. Forage samples were taken and dry matter yields determined for each fertilizer plot and for the two experimental fields.

Water Supply and Irrigation Equipment

Irrigation water was pumped from a 1½-acre pond that has a capacity of approximately 9 acre-feet when filled to spillway level. This capacity is sufficient for a minimum of six 2-in applications to the 5-acre irrigated area.

Two sets of equipment were used. The first system, used for three years, consisted of a gasoline-engine pump with a capacity of 60 gpm at 40 psi. A 3-in main was placed through the center of the field, and a 2-in lateral extended across one-half of the field (Fig. 1). It was equipped with six rotating sprinklers, each flowing at 8 gpm. The lateral covered a 40 x 60-ft area and required 6 hr for a 2-in application. Thus, to cover the 5-acre field, 16 moves of the lateral and a total time of 96 hr were required.

The second system consisted of a 120-gal pump, the 3-in main through the center of the field, and a 3-in lateral across the width of the field with 12 sprinklers. Using the larger lateral and doubling the pump capacity and number of sprinkler heads made it possible to apply 2-in of water in 48 hr with eight moves of the lateral pipe.

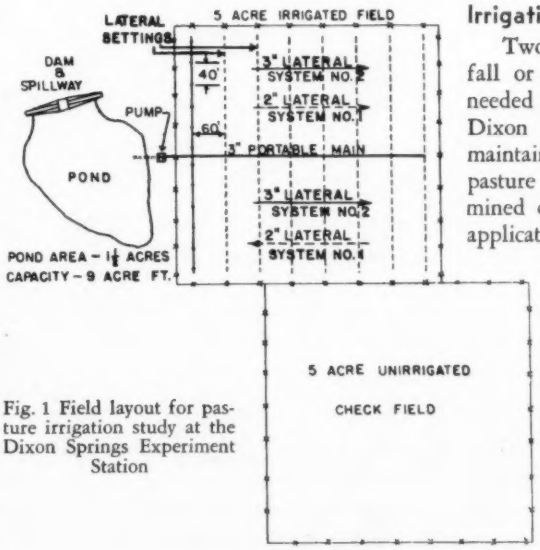

Fig. 1 Field layout for pasture irrigation study at the Dixon Springs Experiment Station

Irrigation Schedule

Two inches of water, either as rainfall or as supplemental irrigation, are needed during a 14-day period at the Dixon Springs Experiment Station to maintain soil moisture and abundant pasture growth (2). It was also determined during the first year that a 2-in application of water was more effective than 1-in applications in terms of usable soil moisture, economy, and greater returns per acre-inch of water applied. Water was applied so that the lower level of usable soil moisture was kept near 35 percent, since field observations indicated that this should be the minimum level of usable soil moisture for continuous pasture growth.

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1954, on a program arranged by the Soil and Water Division.

The authors — BENJAMIN A. JONES, JR., and HOWARD L. WAKELAND—are, respectively, assistant professor and instructor, agricultural engineering department, University of Illinois.

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*Numbers in parentheses refer to the appended bibliography.

Soil Moisture Measurements

Soil moisture measurements were made to determine the effect of irrigation in maintaining usable soil moisture and as an indicator of when irrigation is needed. The plaster of paris moisture block, electrical resistance method developed by Bouyoucos (3, 4) was used to measure the percent of usable soil moisture, i.e., the moisture in the soil that is available for plant use.

In 1948 two groups of Bouyoucos blocks were calibrated and installed in the experimental fields. One group of blocks was located at depths of 3, 9, and 18 in and another group at 1½, 4½, 7½, 10½, 15, 21, and 36 in. Moisture measurements taken at these levels in 1948 and 1949 indicated that soil moisture readings taken at 4, 8, and 12-in depths would give sufficiently accurate indications of soil moisture on the irrigated field (1). Moisture measurements on the irrigated field were made at these levels in 1950, 1951, and 1952. They were also taken at 18, 24, and 36 in on the non-irrigated field because available soil moisture dropped to a lower level in the profile. During the 1953 season, soil moisture measurements were made on the irrigated field only as an indicator of when to irrigate.

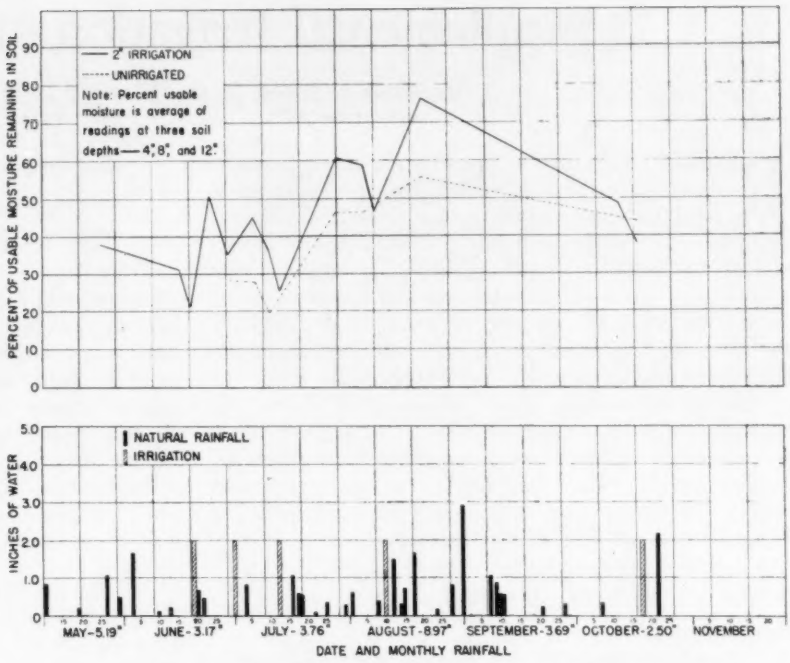

Fig. 2 Effect of rainfall and irrigation on usable soil moisture—1950 grazing season

Rainfall

Analyses were made of rainfall data taken at Dixon Springs and at five weather bureau stations within 35 miles of the experiment station. The 54-year average at the five stations for May through October was 21.29 in, and for the six years covered by the experiments, 21.48 in. At the Dixon Springs Station the six-year average was 21.00 in. The amounts by years for the six-month period indicated were:

1948 — 21.16 in	1951 — 26.39 in
1949 — 25.32 "	1952 — 13.75 "
1950 — 27.28 "	1953 — 12.13 "

Thus, in the experimental period, the rainfall was typical for the area and covered a wide range, from 6.0 in above to 9.2 in below the 54-year average.

An analysis was made to determine the number of years irrigation would have been required to provide moisture equal to the average rainfall plus supplemental irrigation and therefore maintain crop growth at the level of that on the irrigated field. The average rainfall was 21.0 in and the average water application was 13.0 in; or a total average of 34.0 inches of water was used.

In order to apply this amount of water in any year from 1900 to 1947, it would have required a minimum of 2 in in one case and a maximum of 24 in in two of the years. In six years, or 12½ percent of the time, 6 in of supplemental irrigation, or less, would have been needed; 12 in or more would have

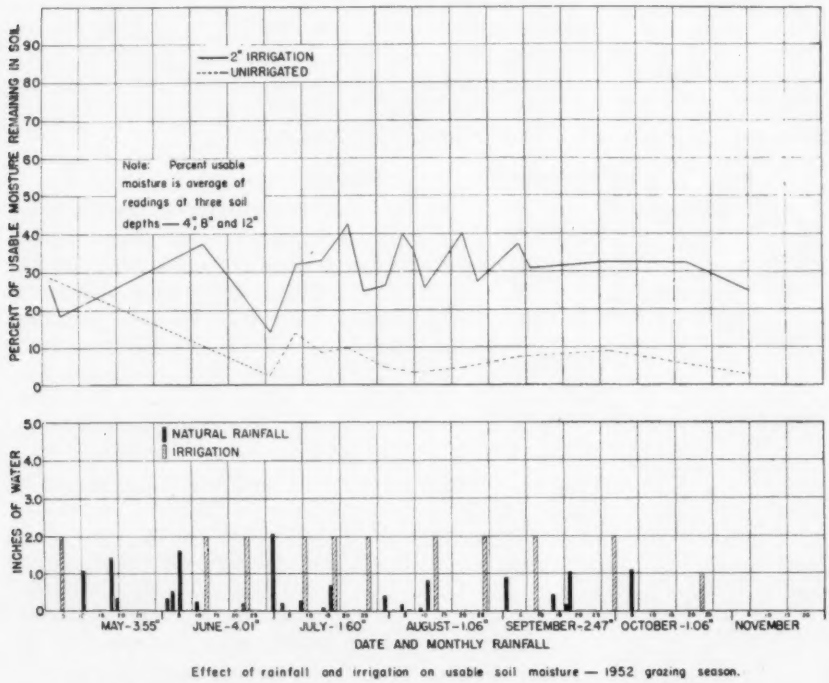

Fig. 3 Effect of rainfall and irrigation on usable soil moisture—1952 grazing season

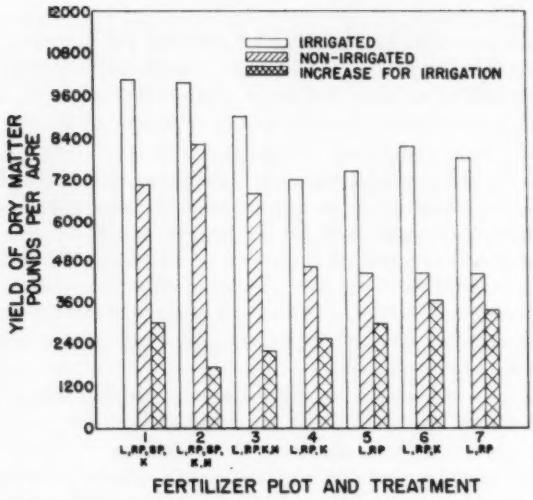

Fig. 4 Average yields of dry matter and results of fertilizer application, 1948-53

been needed in 70 percent of the years. But about half of the time the need for irrigation water would have varied from 14 to 18 in.

Soil Moisture, Frequency, and Amount of Irrigation

It had been determined that the lower limit of usable soil moisture (wilting point) for Grantsburg and Robbs silt loam was approximately 20 percent of the available soil moisture (1). Following field observations it was decided that irrigation should be started when the usable soil moisture was about 35 percent of available moisture so that the field could be completely irrigated before plant growth was retarded.

Soil moisture curves (Figs. 2 and 3) show the needs and effects of irrigation in maintaining soil moisture in years of above-average and below-average rainfall. Fig. 2 shows averages of percent of usable soil moisture remaining in the soil at depths of 1½, 4½, 7½, and 10½ in. Fig. 3 is based on measurements at depths of 4, 8, and 12 in.

The highest rainfall in the 6-year period occurred in 1950 and illustrates irrigation needs in a year of above-average rainfall. However, the rainfall for June and July was less than the "2 in per 14 days" required for abundant forage production, and soil moisture fell below the 35 percent of usable moisture level. On the non-irrigated field it did not go above 35 percent until the third week of July, and forage production was low during this period. The initial sudden drop in available soil moisture on the irrigated field is attributed to the demand of the heavier stand of forage.

The 1952 season had the least rainfall of the years in which usable moisture was measured on both fields. During this season 21 in of irrigation water were applied, 14 in of this amount being applied during June, July, and August. (This was the entire available supply.) The usable moisture on the non-irrigated field was below 10 percent most of the season, and production was low.

Fertilizer Treatment and Pasture Yields

In 1948 the five-acre fields were divided into four plots each for fertilizer treatment studies, and in 1949 the four plots were subdivided into seven plots. The total amounts of each fertilizer applied to the plots during the six years are shown in Table 1.

TABLE 1. FERTILIZER TREATMENTS (POUNDS PER ACRE) ON PLOTS, 1948-1953

Plot	Rock phosphate	Superphosphate, 20%	Potash, 60%	Nitrate, 33½%
1		2,259	950	
2		2,259	950	1,737
3			950	1,737
4	1,000		953	
5	1,000			
6			953	
7				

Original treatment: 3 tons of lime and 1,000 lb of rock phosphate over all plots.

In addition, 320 lb per acre of 10-10-10 applied to check strips in 1953.

The six-year average yield of dry matter in pounds per acre from the soil-treatment plots and the increase from irrigation are shown in Fig. 4. The results indicate that the limestone, rock and superphosphate, and potash treatment was the most productive, that superphosphate was more effective than rock phosphate with irrigation, and that nitrogen was not effective on the irrigated area.

In 1953, 10-10-10 fertilizer was added on check strips on all treatment plots. Those on the irrigated field showed profitable increases in production so that additional fertilizer could have been used. The 10-10-10 fertilizer did not give profitable increases on the non-irrigated field.

The greatest six-year average net return per acre after fertilizer costs on both fields was from the plot which had limestone, rock and superphosphate, and potash. The return was $20 an acre greater than the second highest plots, which had only limestone and rock phosphate. The plots on both fields with nitrogen application showed the least net return per acre (probably because of the high cost of nitrogen).

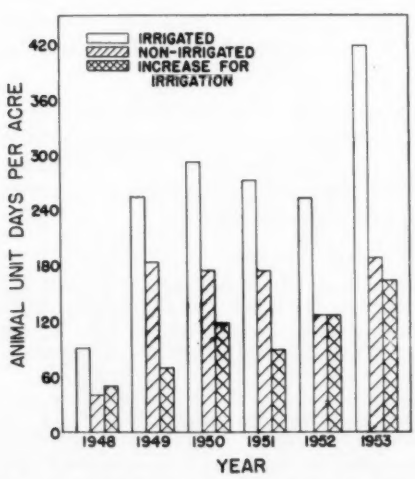

Fig. 5 Pasture days for irrigated and non-irrigated pastures, 1948-1953

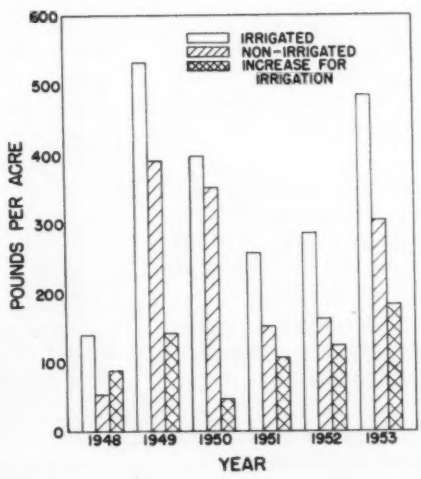

Fig. 6 Animal gains from irrigated and non-irrigated pastures, 1948-1953

Returns from Irrigation

The returns from pasture irrigation may be measured in three ways: *(a)* animal-carrying capacity, *(b)* animal gain, and *(c)* yield of hay.

Carrying Capacity

The annual pasture days (animal unit days per acre) and the increase as a result of irrigation are shown in Fig. 5. Irrigation gave greater carrying capacity and a longer grazing season. Animal units per acre on the irrigated field ranged from 0.82 to 2.14, with a six-year average of 1.45. Animal units on the non-irrigated field ranged from 0.36 to 1.21, with a six-year average of 0.96 per acre. This is an average increase, due to irrigation, of 0.49 animal units, or 51 percent.

During 1948-51 inclusive the fields were pastured the same number of days. In 1952 and 1953, when days pastured were recorded independently for each field, the irrigated field was pastured for 203 and 195 days, respectively, while the non-irrigated area was pastured for 107 and 155 days in the two years. This is an increase, due to irrigation, of 96 days, or 90 percent, in 1952 and 40 days, or 26 percent, in 1953. The six-year average pasture days based on days pastured and animal units per acre showed an increase of 103, or 55 percent.

Animal Gains

Animal gains on both fields and the increase due to irrigation are shown, by years, in Fig. 6. The six-year average animal gain was 347 lb per acre on the irrigated field and 236 lb on the nonirrigated check field. This gave an increase of 111 lb per acre, or 47 percent, due to irrigation.

Hay Production

The dry matter produced, measured on ungrazed small plots, indicated a six-year average yield of 5 tons per acre of dry matter under irrigation as compared with 3½ tons from the non-irrigated field. This was a gain of 1½ tons, or 43 percent.

Does Irrigation Pay?

Based on six-year average, it is possible to estimate the gains due to irrigation and compare them with the cost. In this experiment, 103 animal unit days per acre were gained by irrigation. This additional grazing period, a gain of 55 percent over the non-irrigated area, would be worth varying amounts depending on the cost of other feeding operations. However, this should be a profitable increase if pasture land is limited.

The animal gain can be estimated more definitely. The six-year average annual net increase due to irrigation was 111 lb. animal weight per acre. Reliable estimates for the period allow 20¢ a pound as a fair value. This increased gain gives an increased income of $22.20 an acre.

If the grasses had been harvested for hay, the average gain due to irrigation would have been 1½ tons of dry matter per acre. This increase, if valued at $30 a ton, would have returned an extra $45 an acre.

Thus the increased income due to irrigation, averaged for the six-year period, was $22.20 based on animal gain and $45 an acre based on the value of dry matter in the forage produced.

The yearly cost of operating the irrigation system was calculated at approximately $25 an acre. (The items were 71½ man-hours of labor for the season on the five-acre tract, at 75¢ an hour; 494 gal of gasoline at 25¢ per gal, and maintenance costs on equipment at 3 percent of $1,200, or $36. Exact calculation, $24.88 an acre).

By these comparisons, the gain in animal weight fell short by about $2.70 an acre of meeting the operating and maintenance costs, with no margin for interest on the investment in equipment and source of supply nor for depreciation or profit. Even in the best year of the experiment, an increase of $7.92 above operating and maintenance costs was not sufficient to cover depreciation and interest on investment and provide a profit.

If the irrigated area had not been grazed, and the entire increase in forage had been harvested and marketed as hay, the gain would have amounted to $45 an acre, giving a margin of $20 to cover the overhead costs of interest, depreciation, and profit and the expense of preparing the hay for market. Under these conditions it is doubtful whether the gains from irrigation would allow profitable operation.

A review of the results of this experiment indicate that unusually careful attention to management is required in order for the irrigation of pastures to be profitable. Gains of as much as 1½ tons of dry matter per acre were recorded in the production of forage; in some cases the irrigated field was pastured at the rate of 2.1 animal units per acre, and the pasture season was lengthened. Therefore, further experimentation, especially in the management phase, may point the way to profitable irrigation under these conditions.

CONCLUSIONS

- Management practices must be improved if returns from irrigated pasture are to pay the cost of irrigation.
- The six-year average animal gain was increased 111 lb per acre, or 47 percent, on the irrigated field. However, at 20¢ per lb of gain, this increase was not sufficient to pay operating and maintenance costs.
- Animal-carrying capacity measured by pastured days was increased by 55 percent, or 103 pasture days.
- The six-year average increase in return due to irrigation, with hay valued at $30 a ton of dry matter, was approximately $45, which must cover operating, maintenance, depreciation, interest on investment and other costs before a profit is realized.
- Fertilizer treatment of limestone, rock and superphosphate and potash was the most productive with irrigation. Superphosphate produced more forage than rock phosphate and nitrogen did not provide enough response to pay for its cost.

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Good Irrigation Vital in Mosquito Control

Marshall B. Rainey

SEVERE mosquito problems are a by-product of faulty irrigation throughout the western states. This is especially true of some of the older irrigation projects where conditions favorable to prolific mosquito production have been developing for many years. Those who live or work in such areas are familiar with the hordes of mosquitoes frequently encountered, and fully appreciate the annoyance and discomfort that these bloodsucking insects impose upon man and farm animals. High populations of biting mosquitoes may also cause important economic losses by lowering beef and milk production, by reducing the efficiency of agricultural and industrial workers, by interfering with recreational enterprises, and by lessening the value of farms or other real estate.

In addition to their nuisance and economic significance, mosquitoes are vectors of serious diseases of man and animals. During the past several years, studies have shown that mosquitoes are the principal vectors of virus encephalitis, the disease of man and horses commonly known as sleeping sickness, or brain fever. The common encephalitis mosquito, *Culex tarsalis,* is produced in a wide variety of habitats. In the West, its breeding places are often directly associated with irrigation.

The tremendous numbers of mosquitoes that frequently occur in irrigated areas, particularly *C. tarsalis,* are of vital concern to health agencies. Recognizing the need for a thorough understanding of the factors responsible for such populations, the U.S. Public Health Service is cooperating with other federal and state agencies on studies in several irrigated areas having widely different conditions. Some of the more significant findings of these field investigations are discussed in this paper; other, more detailed information will be found in the progress reports cited.

Problems of control are directly associated with primary water-conveyance systems, application of water, and removal of excess water from the land

All mosquitoes develop in water. In order for the aquatic wrigglers to mature and produce adults, the water must usually be present for a minimum of 5 days. Flooding for this period, however, is detrimental to all common field crops except rice. Fields that produce good healthy crops will not produce mosquitoes.

Mosquito problems are frequently related to both the engineering and agricultural phases of irrigation. Climate, topography, soils, crops, and water management practices may all be involved in the development of conditions favorable to mosquito breeding in irrigated areas of the western states. On the basis of present information, the major sources of mosquitoes associated with irrigation can be grouped into two principal categories: first, those related to the primary water conveyance systems, and, second, those related to the application of water and the removal of the excess from the land.

Water Conveyance Systems

In the first category, there are several types of water areas that produce mosquitoes. Examples are ponded areas where canals block natural drainageways; leakage from turnout gates, drops, and other water-control devices; residual water in turnouts, stilling basins, and other hydraulic structures. Although each of these habitats may contribute to the overall mosquito problem, they are usually of minor importance because of their small total area.

Seeps, on the other hand, are the major mosquito-producing habitats associated with irrigation canals. In areas where unlined canals are used to transport water from the point of diversion to the irrigated lands, a large percentage of the water is frequently lost by seepage and leakage through the earth beds and banks. These losses, in addition to deep percolation from irrigated lands, often cause the water table of an area to rise considerably, and in some valleys numerous marshy seeps are formed. Such seepage severely damages valuable agricultural lands and creates extensive areas highly suitable for mosquito breeding. Moreover, these marshes have been found to be important sources of *C. tarsalis.*

In the summer of 1951, field studies were made at Mitchell, Nebr., to determine the relative abundance of mosquito species produced in irrigation seeps (1)*. During the period of study which extended from early July to late September, 42 out of 50 seeps, both permanent and semipermanent, contained *C. tarsalis.* In addition, this encephalitis mosquito accounted for 74 percent of all the larvae col-

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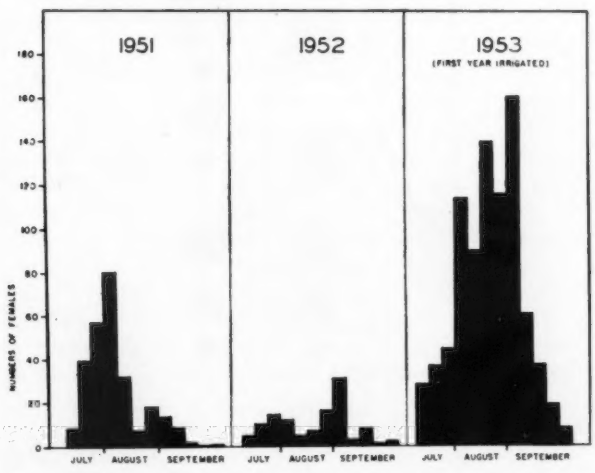

Fig. 1 Populations of *Culex tarsalis* females, Angostura Irrigation Project, South Dakota. Average of the highest catch of the week from each of the four light traps operated on the project, July 7 to September 29

*Numbers in parentheses refer to the appended bibliography.

lected. Approximately 10 percent were other pestiferous species.

A similar survey conducted in Scotts Bluff County, Nebraska, during the summer of 1953, showed that seeps were responsible for more than 80 percent of the total production of *C. tarsalis* (2).

A third study, at the Angostura Project, South Dakota, has shown that irrigation seeps are important sources of *C. tarsalis* in that area, too. During preirrigation studies at Angostura, it was found that natural seeps were present in draws located on non-irrigable lands within the project area (3, 4). In 1952, before the delivery of irrigation water to the project, the index of mosquito production† for the natural seeps was 1.1. In 1953, when water was diverted into the canals for the first time, the natural seeps increased in size, many new ones appeared, and the production index for all seeps jumped to 86.0. More important, however, is the fact that *C. tarsalis* comprised 78 percent of more than 14,000 larvae collected from this type of habitat. The increase in *C. tarsalis* larvae during the first year of irrigation at Angostura was also reflected by a substantial increase in index numbers of adults (Fig. 1). The "adult indexes" were computed by averaging the highest catch of the week from each of the 4 light traps which were operated on the project. In 1953, in spite of less summer rainfall, all weekly indexes, except those for July, were higher than those for the corresponding weeks of 1951 or 1952.

The results of the field studies in Nebraska and South Dakota, which have been confirmed by less intensive observations in various other parts of the West, all indicate that seeps are the major mosquito sources resulting from irrigation conveyance and distribution systems.

Water Application and Drainage

Breeding places in the second category of mosquito sources, namely, those associated with the application of water to the land and the disposal of excess, are of prime importance in most irrigated areas. These habitats may occur on both irrigated and non-irrigated land. Mosquito breeding on irrigated fields has been found to occur most often on those used for pastures and other close-growing forage crops. Comparatively few mosquitoes are produced on fields planted to row crops because such crops cannot survive flooding for periods long enough for the larvae to complete their development. It is the residual water that remains on the fields for extended periods that results in mosquito production. A significant amount of breeding also occurs in residual water in the field irrigation ditches and field drains.

Mosquito breeding on non-irrigated land, termed off-field production, has been found in wasteland areas, borrow pits, roadside ditches, and various other places flooded by excess irrigation water. The major off-field sources are

†Production index = (average number of larvae per dip) × (breeding area in square feet) ÷ 500,000.

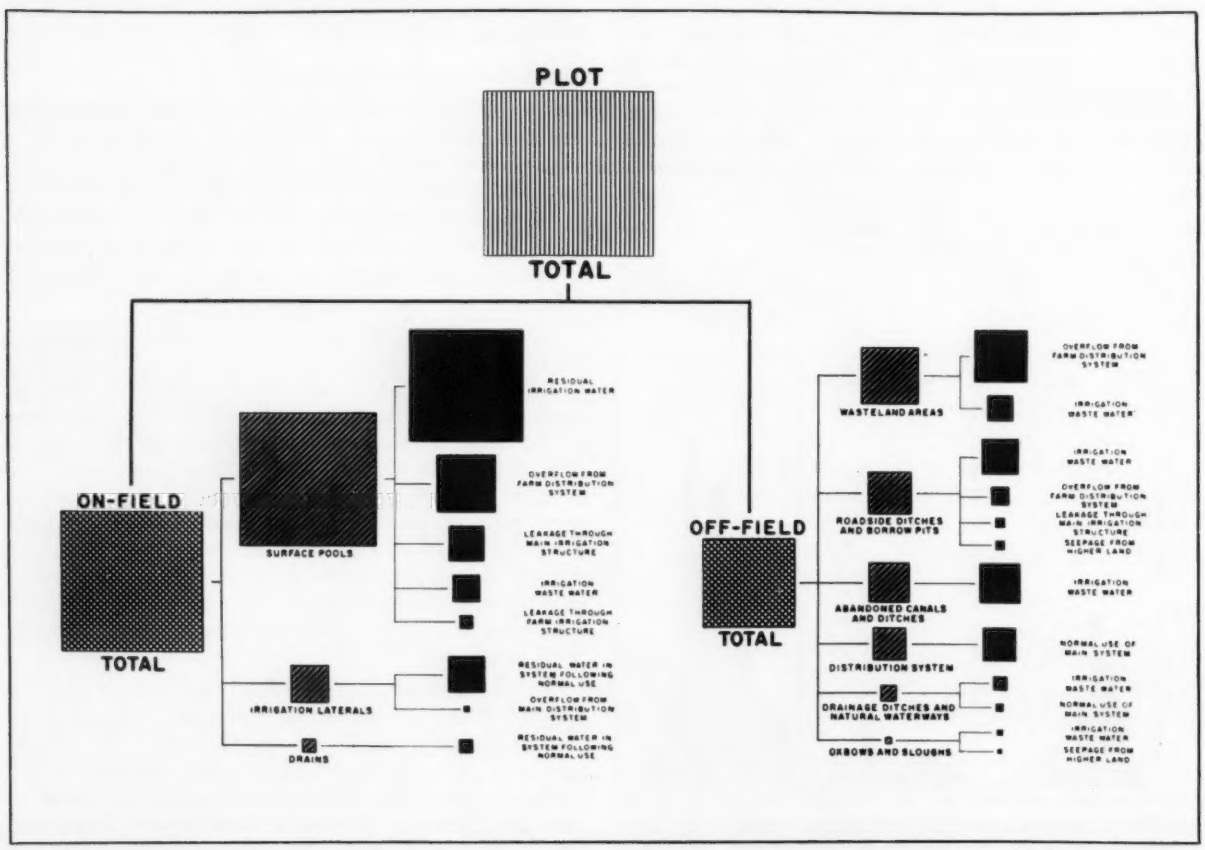

Fig. 2 Mosquito production according to location, habitats, and sources of water on a study plot, Milk River Irrigation Project, Montana, 1952. The values shown are based on calculated production indexes for the entire irrigation season

usually directly related to inadequate drainage. Both farmstead and trunk drainage are frequently involved.

Field studies on mosquito problems associated with water application and drainage have been made in several irrigated areas. These study areas were chosen to represent different conditions with respect to topography, soils, and crops. For example, in 1951, studies made near Minatare, Nebr., in the North Platte Valley, compared mosquito production on a 245-acre plot in the bottom lands and a 2,300-acre plot on the upper terraces (5). On the bottom land plot, the soils were tight, drainage was poor, and the application of excessive amounts of irrigation water aggravated waterlogging and alkali problems. At the time of the observations, most of the land was utilized for pastures and wild hay meadows. The unleveled fields were wild flooded and when water was applied in sufficient quantity to cover the high spots, excessive ponding occurred in the low areas. This practice tended to drown out the better species of forage grasses in the low areas and encouraged invasion of sedges, rushes, and other water-loving plants. In contrast, the upper-terrace plot included lands that were well suited to the production of various irrigated crops such as sugar beets, potatoes, beans, alfalfa, and small grains. The fine sandy loam was ideal for irrigation. The fields were leveled, and the drainage ditches for removal of excess irrigation water were well maintained.

High mosquito production occurred on the bottom land plot, where according to production indexes, 96 percent of all the mosquito breeding during the season occurred in pools on the fields. These collections of surface water occurred principally in depressions on the irrigated pastures and hay meadows. Residual water in field laterals also caused considerable on-field mosquito breeding. Much of the off-field mosquito production was due to the poor condition of the farm supply laterals and water-control structures. This resulted in overflow, seepage, and leakage which flooded low areas, borrow pits, and roadside ditches. All types of bottomland habitats produced large numbers of *C. tarsalis* and pest mosquitoes. The mosquito production indexes for the upper-terrace plot were, by contrast, relatively low. Breeding occurred principally in irrigation waste water that ponded in a few roadside ditches and in some low areas at the ends of fields.

Studies made in 1952 in the Milk River Valley, Montana, further illustrate the importance of mosquito habitats related to the use of irrigation water (6). The 5,000-acre study plot on this project was characterized by flat slopes and fine-textured soils having low intake rates. The principal irrigated crops included pasture, alfalfa, western wheat grass (commonly known as bluejoint), small grains, and sugar beets. Many of the fields, particularly those used for forage crops, had not been properly prepared for irrigation, and over many years, little attention had been given to improved irrigation methods or water management practices.

Results of the Milk River studies are graphically shown in Fig. 2. According to production indexes, approximately 71 percent of all mosquito breeding occurred on irrigated fields consisting principally of pastures, alfalfa, and bluejoint. Most of this breeding occurred in surface pools of residual irrigation water. Overflow of farm distribution systems, leakage through water-control structures, and waste water from adjoining fields also caused stagnant surface pools. It was observed that when the water stood long enough to produce mosquitoes, the better forage grasses and legumes were killed. Some mosquito breeding occurred in the residual water in field laterals and field drains.

Off-field breeding places accounted for 29 percent of the total mosquito production index on the plot (Fig. 2). These mosquito sources included numerous undrained or poorly drained wasteland areas, roadside ditches, and borrow pits in which irrigation waste water and overflow from farm distribution systems accumulated.

Throughout the study area, there were high populations both of pest mosquitoes and of the encephalitis vector.

In contrast to the preceding example, studies at the Mirage Flats Project in northwestern Nebraska clearly indicated that where irrigated farms have been properly developed and good water-management practices are employed, mosquito production can be held to a minimum. When this project was initially developed, all farm units were carefully planned and prepared for irrigation. The fields were leveled and graded, and irrigation methods were selected on the basis of topography, soils, and crops. In addition, a good system of main drains was installed when the project was constructed. Studies made during the summer of 1950 (7), two years after the initiation of irrigation, indicated that mosquito production on the project was very low. No breeding was found on the irrigated fields. Undrained roadside ditches, in which irrigation waste water accumulated, were the principal sources of mosquitoes.

The studies of mosquito production associated with the use of irrigation water have shown that the most severe problems are frequently caused by a combination of poor irrigation and poor drainage practices employed by the water users. These practices include inadequate preparation of land, unsuitable irrigation methods, poor water management, improper disposal of excess water, and poor maintenance of distribution and drainage systems. These mosquito studies have also shown that the interests of public health are served by the use of improved irrigation and drainage practices that have been developed to conserve both soil and water.

SUMMARY AND CONCLUSIONS

The major mosquito sources associated with the irrigation of common field crops can be grouped into two principal categories: first, those related to the primary water conveyance systems; and second, those related to the application of water and the removal of the excess from the land.

Seepage areas were found to be the most productive mosquito breeding places associated with irrigation canals and a principal source of *C. tarsalis,* the common encephalitis mosquito of the western states. Mosquito sources associated with water application and drainage are of prime importance in many irrigated areas. These habitats may occur on the irrigated fields or on nonirrigated lands. Breeding on irrigated fields was found most often on those used for pastures and other close-growing forage crops. Comparatively little mosquito production occurred on fields used for row crops, since such crops cannot survive flooding for extended periods. Off-field mosquito breeding was found in wasteland areas, borrow pits, roadside ditches, and numerous other places flooded by excess irrigation water.

(Continued on page 191)

Septic Tanks: Studies and Performance

S. R. Weibel

THE studies discussed in this paper were intended primarily for the unsewered urban fringe areas. However, the same progress in transportation and electrification which has enabled modern living in fringe areas has also brought modern living to the farm. Fundamentally, the waste problem and its solution are much the same. The farmer is indeed in the enviable position of having ample space, possibly a choice of soil and equipment, ability and habits which make it convenient to take care of waste-disposal facilities.

The number of individual household sewage-disposal systems in this country probably now exceeds 6 million, serving some 24 million persons, with recent new residence construction running some 30 per cent to such systems. The common system is a septic tank followed by subsurface application to the soil by either shallow trenches or deeper pits. The septic tank serves as a settling, digestion and solids storage tank, functionally preparing the sewage for the necessary further treatment and absorption in the soil. If surface and subsoils are suitably absorptive the shallow-trench system is preferred practice; if not, and if porous soils are reasonably available at deeper depths, pits with open-joint walls, called seepage pits, are used. As the latter penetrate the deeper soils, they are of greater hazard to groundwater pollution. Where the soil offers no reasonable absorption possibilities, the common alternative is a subsurface sand filter, either in the form of a trench or a bed, discharging to a surface watercourse. The cesspool, which is similar in construction to a seepage pit but receives raw household waste, finds scattered use, but it is generally recognized as a source of difficulty in other than the most porous soils. Because of this and its pollutional liabilities the cesspool is not recommended nor approved in many states and local areas.

With entry of the federal government into private housing, to the extent of insuring mortgages, it became evident, in attempting to settle on design specifications, that there was considerable diversity in state and local standards over the country. It became evident too that there were many unresolved problems in this field due partly to an underlying scarcity of factual data upon which to base proper design. This led to joint sponsorship, by the federal Housing and Home Finance Agency and the Public Health Service, of studies on household sewage-disposal systems. These were conducted by the Public Health Service's Robert A. Taft Sanitary Engineering Center at Cincinnati, Ohio, the active work starting in 1947.

A poll of local health departments over the country in 1947 indicated that only 40 per cent of the systems then existing had been installed under organized control. Prominent among the difficulties existent were evidences of failure to design on the basis of proper soil investigation, the tendency to skimp on tank capacity, poor layout, careless construction, and problem areas amounting to misapplication of this type system in a totally unsuitable soil environment. However, design and installation shortcomings were but partly responsible for the many failures. At least equally responsible were the delinquencies in servicing the septic tanks, overdue in more than 50 per cent of the calls according to servicemen, resulting in sludge spillovers and consequent clogging of the soil absorption system.

A consideration of new problems involved in sewage disposal in areas of limited ground space

During the period of investigation by the Public Health Service, 1947-1953, some 350 household sewage-disposal systems in several areas over the United States were examined in the field. At the Center in Cincinnati, 33 full-size household-type septic tanks were operated experimentally to determine influencing elements, such as size, shape, compartmentation and flow appurtenances. Studies of the effects of ground garbage, detergents, water-softener brines, and sodium hydroxide, were also conducted in the full size tanks. Laboratory experiments on anaerobic digestion, under the influences above-mentioned, and on the soil-clogging effects of sewage, effluents, and home laundry waters were undertaken. Experimental studies of the soil water percolation test were made, and factual data on soils, climate and soil-water characteristics developed in agricultural circles were evaluated for use in this field. A brief presentation of some of the results of these studies and their applications follows. The details on these and allied matters are contained in reports now available or in preparation on the work (1, 2, 3)*.

The volume of wastes from individual homes, as reflected in metered water consumption, varies considerably, depending on house size and living habits. Winter water consumption averages 39 gal per person per day, ranging from 8 to 150 gal among different homes. Automatic dishwashing machines and garbage grinders add but little to the waste volume but automatic-sequence laundering machines increase water use by some 17 gal per person per day on the average. Among homes of four or less bedrooms, which represents about 99 per cent of the recent home building in the United States, the highest per capita water consumption, and the highest person occupancy per bedroom, are found in the smallest homes. These decrease as the size of home increases, within the group above-mentioned.

The variable character of residential wastes is influenced by individual family habits and practices in the use of cleansing materials and appliances. Variation among different installations is wide. Changes in ownership and occupancy of a particular system also introduces variation. As a consequence the yardstick, number-of-occupants, is losing favor in preference to the number-of-bedrooms as a more stable measure of loading potentiality. Inherent in this measure is, for instance, capacity for week-end or overnight guests. Many times the initial occupancy and appliance circumstances, as well as those consequent to future ownership

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*Numbers in parentheses refer to the appended bibliography.

changes, are unknown. Coupling this with growing trends toward general use of household appliances, thoughts in some quarters run to designing for the entire loading potentiality in the initial system. This has merit in that ownership changes are often made without knowledge of what limitations there may be in the existing sewage disposal facilities.

Concerning studies of septic tank design elements, the importance of capacity became very evident. Beyond effecting the solids removal function, capacity is required for solids storage. The amount of storage capacity is a matter of choice, depending on the cost of such storage as compared with costs of cleaning septic tank at intervals governed by storage capacity. Both field and laboratory studies indicate that the larger the tank the better the solids removal performance. Tanks having 125 to 175 gal per capita capacity were found to effect average suspended solids removal in household practice. In experimentally operated tanks a 500-gal single tank removed 60 per cent suspended solids as against about 80 percent for a 2,000-gal single tank. Tanks of some 300 gal and smaller capacity quickly consumed solids storage space and thereafter failed in solids removal. Because of relatively high tank servicing costs in the United States liberal capacity is of economic advantage. Other advantages accrue, such as improved solids removal and less interference with sustained performance in the longer operating intervals.

Among newer household appliance factors the only one requiring expansion of tank capacity is the garbage grinder. Field studies indicate 77 per cent increase in sludge and scum accumulations, with the increase in scum alone, 210 per cent, and in sludge alone, 31 per cent, over the non-garbage installation. Increase in flow due to automatic laundering machines was not significant in effect to tank capacity, although it necessitates adjustment of soil-absorption design areas, as does garbage also. No tank adjustments for detergent use, nor for ion exchange water-softener brine waste, are indicated.

Septic tank capacities necessary to provide reasonable suspended solids removal performance during intervals of about ten years between cleanings, on the average, are listed in Table 1. The table also includes the sizes necessary to provide the same average ten year operating interval where ground garbage is involved, a 50 per cent increase in capacity. The ten-year average design operating interval is not to be construed as a servicing criterion for the individual installation. Variation in solids accumulation rates among seemingly similar households is wide. Low-accumulation-rate cases may be operated for more than ten years before cleaning becomes necessary, whereas high-accumulation-rate cases may have to clean within two or three years. Servicing criteria are covered in a later paragraph.

TABLE 1. MINIMUM LIQUID CAPACITIES OF HOUSEHOLD SEPTIC TANKS

Number of bedrooms	Minimum liquid capacity, gal	
	Without garbage	With garbage
2 or less	500	750
3	600	900
4	650	975
Over 4	160 per bedroom	240 per bedroom

Rectangular, vertical round and similar straight vertical-side tanks perform equally well at the same capacity. Non-straight vertical-side tanks, such as horizontal rounds, also perform well if designed to realize solids storage capacity equal to the others. Liquid depths of 2½ to 5 ft gave good performance, better at the shallower depth.

Multicompartmentation studies indicate usefulness of such arrangements, in two ways. They may be utilized to broaden the variety of acceptable tanks, with performance at least equal to a single tank of the same capacity. Two, three, and four equal compartments are examples of this. They may also be utilized to obtain higher performance over a single tank of equal capacity, but the design narrows to certain arrangements to accomplish this aim, such as two compartments, with one-half to two-thirds total capacity in the first. Suspended solids removals as high as 80 per cent may thus be obtained, as compared with 60 per cent for the single tank of the same capacity. This advantage does not accrue in three equal compartments, nor in two with a small first compartment, nor fully in four equal compartments. In comparing relative costs consideration should be given not only to first cost but the cost of servicing multicompartments. The well-designed single tank still enjoys a record of good performance in well-drained soil areas. Under less favorable circumstances, including those of space limitation for relocation of absorption systems, multicompartmentation may find most interest.

It was found experimentally that the location of the bottom of an outlet tee determines the distribution of available storage space among scum and sludge. Further, scum and sludge accumulations approach limiting distances above and below the bottom of the outlet fixture, beyond which solids retention fails. For sludge, such distances are related to liquid surface area, and range from 1.8 ft for 12.5 sq ft surface area to 0.5 ft for 30.0 sq ft, under simulated household flow patterns. Limiting distance for scum, not investigated experimentally, but with limited field experience, is suggested as 3 in for practical purposes. Deducting the volumes represented by the above distances from capacity, the residual space is submerged solids capacity. This may be apportioned among scum and sludge proportional to accumulation rates. The apportionment amounts to 25 per cent for submerged scum storage space in non-garbage tanks; 44 per cent in garbage tanks. The outlet bottom is set accordingly. For practical convenience outlet design statistics, expressed as percentages of tank liquid depth, are presented in Table 2. These apply for straight vertical-side tanks. For other shapes, such as horizontal rounds, a separate computation must be made. Total freeboard is suggested as outlet projection above water line plus one inch.

TABLE 2. LOCATION TOP AND BOTTOM OF OUTLET TEE OR BAFFLE

Total liquid tank capacity, gal	Tank receiving sewage		Tank receiving sewage and garbage	
	Projection above water line*	Penetration below water line*	Projection above water line*	Penetration below water line*
500	12	22	-	-
750	12	24	18	38
1,000	12	26	18	41

* Percent of liquid depth.

In designing inlet tees or baffles, projection to one inch below roof and downward penetration the same distance, from inlet invert to bottom of fixture, as the outlet, are suggested. A 3-in drop from inlet invert to water line is customary. In multicompartmentation, each compartment was provided with inlet and outlet fixtures in the studies. The 3-in drop to water line might best be provided in the first compartment.

The soil absorption system involves factors as the volume of waste, its clogging characteristics after passage through the tank, and the absorption characteristics of the soil on site. A very high unit waste loading is imposed on the soil in such systems, in comparison to rainfall and irrigation loadings. Rainfall averages 30 to 50 in per year in the United States, with extremes of 150 in, resulting in some 20 to 40 in of absorption, reaching 100 in at the extreme. Irrigation amounts to about 100 in applied per year. In contrast, household absorption system trench bottoms receive from 200 to 1,000 in of effluent annually, running to over 2,000 in in extreme cases. To this volume is added the complicating influence of sewage constituents.

Physical, biological, and chemical influences in soil absorption of effluent were studied. The physical plugging of soil pores increases as the amount of suspended matter applied increases. Biological influences in agricultural water spreading amount to clogging soil pores with biological bodies and by-products or destruction of soil structure by biologic activity. In septic-tank effluent application, however, the biologic activity tends to reduce the clogging tendencies of other factors. Chemical clogging, through ion exchange and breakdown of soil structure, is a common agricultural irrigation problem, due to waters relatively high in sodium. This factor also is present in the household system because of increase in sodium ratio as waters are used in household operations.

Clarified fresh sewage clogs soil more rapidly than septic effluent pound for pound of solids; effluent solids from tanks receiving ground garbage and sewage similarly clog soil more rapidly than those of sewage-tank effluent; disinfected effluent clogs soil more rapidly than biologically active effluent. Concerning the influence of household appliances and practices, other than garbage, it is found that a slight shortening of absorption field life may attend inclusion of waste water-softener brines. Use of detergents instead of soap may also slightly shorten absorption field life under some circumstances.

Evaluating various influences on soil-absorption characteristics, it appears that two, namely, the increase in waste volume attending use of automatic clothes washers and the change in clogging character of waste where ground garbage is included, should be recognized for readjustment of the soil absorption system design values originally derived from the Ryon studies of the 1920's. The adjusted design values are given in Table 3.

TABLE 3. PERCOLATION RATE AND DESIGN ABSORPTION AREAS

Percolation rate (minutes for water to fall one inch)	Required absorption area (Square feet of absorption trench bottom per bedroom)			
	Without garbage grinder or auto. washer	With garbage grinder	With auto. washer	With both garbage grinder and auto. washer
2 or less	50	65	75	85
3	60	75	85	100
4	70	85	95	115
5	75	90	105	125
10	100	120	135	165
15	115	140	160	190
30	150	180	205	250
45	180	215	245	300
60	200	240	275	330
Over 60	(Unsuitable for shallow absorption system. Investigate for seepage pit or subsurface filter arrangement.)			

A basic problem is the estimation of absorption characteristics of a soil and its interpretation in the particular site environment. Considering the latter, there are certain soil environments not at all suitable for housing development on the basis of individual soil absorption-type disposal systems. These include impervious soils, pervious upper soils underlain by impervious soil or water table within four feet of the surface, and pervious soils lying in an impervious underground basin. In the latter cases, the disarming success of test results at the shallow depths, fortified sometimes by history of successful operation of an existing isolated system or two can lead to failure when the large loadings of a subdivision are imposed. Such areas have been trouble spots under subdivision development.

Several clues to soil permeability are of some value in appraising soil, but the only really safe basis is the percolation test. Agricultural soil survey reports are helpful in the United States. Visual inspection of soil texture, structure, and color on site are also of interest. Texture, or elemental particle-size distribution, is reliable as a clue to pore space and water-absorption quality only in sandy soils. In heavier soils the elementary particles clumped into secondary larger particles, termed structure, becomes the more important clue as the secondary particles govern pore space and water-absorption value. Color may indicate history of favorable or unfavorable oxidation conditions through movement of air and water. Bright reddish-brown to yellow colors throughout a soil profile are typical of favorable soil. Light gray topsoil and drab, mottled subsoil reflects the opposite.

The quantitative percolation test for application in this field was proposed by Ryon (4) who developed an empirical relationship between soil absorption capacity, as measured by a water percolation test on site, and permissible effluent loading per unit of trench bottom area. As most of the systems studied by Ryon had operated some 20 years before failure, systems designed on the basis of that work have a 20-year life expectancy, under conditions of loading up to the 1920's.

Investigation of the percolation test was included in the Public Health Service studies. As a result a suggested fundamental and objective procedure is offered. This procedure is essential for clay soils and cases where no experience with either the test methods or a particular soil is available. As local experience is gained the procedure may be used to check possibly shorter procedures suitable for local circumstances.

SUGGESTED PERCOLATION TEST

1 *Number and location of tests:* Six or more tests shall be made in separate test holes spaced uniformly over the proposed absorption field site.

2 *Type of test hole:* Dig or bore a hole, with horizontal dimensions of from 4 to 12 in and vertical sides, to the depth of the proposed absorption trench. In order to save time, labor and volume of water required per test, the holes can be bored with a 4-in auger.

3 *Preparation of test hole:* Carefully scratch the bottom and sides of the hole with a knife blade or sharp pointed instrument in order to remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Remove all loose material from the hole. Add 2 in of coarse sand or fine gravel to protect the bottom from scouring and sediment.

4 *Saturation and swelling of the soil:* Carefully fill the hole with clear water to a minimum depth of 12 in over the gravel. By refilling if necessary, or by supplying a surplus reservoir of water, such as in an automatic siphon, keep water in the hole for at least 4 hr and preferably over night. Allow the soil to swell over night. This saturation procedure insures that the soil is given the opportunity to swell and approach the condition that it will be in during the wettest season of the year. Thus the test will give comparable results in the same soil whether made in a dry or a wet season.

In sandy soils containing little or no clay the swelling procedure is not essential and the test may be made as described under item

5C below, after the water from one filling of the hole has completely seeped away.

5 *Percolation rate measurement:* With the exception of sandy soils percolation rate measurements shall be made on the day following the procedure described under item 4 above:

(a) If water remains in the test hole after the overnight swelling period, adjust the depth to approximately 6 in over the gravel. From a fixed reference point measure the drop in water level over a 30-min period. This drop is used to calculate the percolation rate.

(b) If no water remains in the hole after the overnight swelling period, add clear water to bring the depth of water in the hole to approximately 6 in over the gravel. From a fixed reference point measure the drop in water level at approximately 30-min intervals for 4 hr, refilling 6 in over the gravel as necessary. The drop that occurs during the final 30-min period is used to calculate the percolation rate. The drops during prior periods provide information for possible modification of the procedure to suit local circumstances.

(c) In sandy soils (or other soils in which the first 6 in of water seeps away in less than 30 min, after the overnight swelling period) the time interval between measurements shall be taken as 10 min and the test run for one hour. The drop that occurs during the final 10 min is used to calculate the percolation rate.

6 *Additional criteria for judging soil suitability:* In areas of shallow ground water, the depth to the water table shall be determined. If for any extended period during the year the water table is normally at a depth of less than 4 ft, the results of the percolation test should be applied with caution. The case also warrants special consideration if impermeable layers are found at depths less than 4 ft.

Suggested design areas for soil absorption trench type systems are presented in Table 3. These take into account recent water consumption data, effects of garbage grinders, and automatic sequence washers, the original Ryon allowable sewage loading data (4), and additional data on clogged systems, treated by modern statistical approaches to arrive at the values given.

In this area the question of freezing may be of interest. Sources of experience close to installation and servicing of household systems in our northern states and in Canada were solicited in this connection. The incidence of freezing in the usual shallow household system is very small. Unprotected excavation and frozen backfill should be avoided. Pipe lines under areas usually cleared of snow, such as driveways, should be insulated. There have been troubles from failure to observe these precautions.

From the physical simplicity and minimal maintenance demands of the household septic tank-soil absorption system one would little suspect that its behavior is as intricate and effective as its highly mechanized, professionally operated community brother, nor that it operates under normal load variations which are ofttimes quite upsetting to the latter. Nonetheless, the household system is not foolproof and can fail from carelessness in the home and from failure to remove accumulated solids from the tank when necessary. Reasonable use of household disinfectants and cleansing agents is not considered seriously damaging to the system. Excessive use can cause serious damage. As for maintenance, annual gaging of tank scum and sludge will indicate their approach on the critical distances above and below the bottom of the outlet tee or baffle mentioned earlier, at either of which the tank should be cleaned. For practical gaging purposes a strip of turkish toweling tacked along a stick lowered vertically to tank bottom through an outlet tee or baffle and left in contact a few minutes will indicate sludge level. A hinged flap on a stick serves to locate bottom of scum and bottom of outlet. Many failures originate in delinquencies in removing accumulated solids from the tank, sometimes because the homeowner is not aware that there are maintenance responsibilities. A leaflet "Septic Tank Care" (5) has been made available in recent years to assist the homeowner in understanding the system and its responsibilities.

In considering the installation of a system, local guidance may be obtained, in areas with organized control, from the agency authorized to issue permits, approve proposed plans and inspect systems. If such assistance it not available it may be obtained from county or state health departments.

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Irrigation in Mosquito Control

(Continued from page 187)

The presence of high mosquito populations in irrigated areas usually indicates a general disregard for good irrigation and drainage practices. Good irrigation requires the use of conservation measures that will insure high crop production without the waste of either soil or water. The application of these conservation measures will also prevent conditions that cause severe mosquito problems. Experience has demonstrated that the agricultural benefits derived from good irrigation and drainage practices exceed the cost of applying them. Freedom from the hazard of encephalitis and mosquito annoyance are extra dividends derived from good irrigation.

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INSTRUMENT NEWS

KARL NORRIS, Editor

Sponsored by the ASAE Committee on Instrumentation and Controls. Contributions on agricultural applications of instruments and controls and related problems are invited, and should be submitted direct to K. H. Norris, Agricultural Research Center, Beltsville, Md.

Psychrometric Equipment for Recording Potentiometers

B. C. Haynes, Jr. and L. L. Smith
Assoc. Member ASAE Assoc. Member ASAE

NUMEROUS methods have been evolved, by various researchers, to develop suitable wet-bulb equipment for obtaining continuous records of wet and dry-bulb temperatures. Equipment suitable for a wide range of psychrometric conditions was devised recently by Henderson.* This equipment was not provided with a source of constant-velocity air flow, hence it is necessary to make provisions for proper air flow in each installation where the equipment is used. To have maximum usefulness, psychrometric equipment for recorders should combine portability with accuracy, consistency, serviceability and ease of maintenance, and should be completely self-contained.

With the above requirements in mind, the authors commenced design and fabrication of psychrometric equipment for seed-drying-rate studies being conducted at the University of Georgia in cooperation with the U.S. Department of Agriculture. The resulting equipment was completed during November, 1953, and incorporated a modification of the wet-bulb design arrived at by Henderson.

Six portable units were constructed and checked, in a conventional forced-draft oven, against a standard wet-bulb mercury thermometer suspended in the exhaust tube of the oven. The rate of air flow past the thermometer bulb was on the order of 1100 fpm. Checks were made at dry-bulb temperatures of approximately 80, 100, 120, 140, and 160 F, measured by means of the dry-bulb thermocouple of the motor-driven psychrometric unit being tested. All six unit wet-bulbs checked closely with the wet-bulb thermometer used as a standard. The maximum error, encountered at 160 F dry-bulb and 80 F wet-bulb depression, was approximately ¼ F wet-bulb. This error is in the range of 0.3 percent of the wet-bulb depression.

Several of the units, checked at 190 F dry-bulb in another test chamber, gave wet-bulb readings accurate to within 1.5 percent of a 100 F wet-bulb depression as calculated on a constant dew-point basis from intake air conditions. The water reservoirs of the units tested at high temperatures suffered some minor deformation of the plexiglas used in construction, hence it was decided to reduce the maximum test temperature to 160 F.

In operation the water reservoir is inverted and filled with distilled water. The intake tube is positioned in the half circle at the bottom of the reservoir. A length of wet-bulb wick is tied at one end and the open end is slipped onto the wet-bulb stem, around the bend, and down into the wet-bulb well about ½ in. The wet-bulb assembly is fitted into the drilled hole in the underside of the intake tube in such a manner that the brass tip projects toward the end of the longer leg. The two halves of the reservoir and wet-bulb assembly are clamped around the air intake tube and held in place by a machine screw. The intake tube, reservoir, and wet-bulb assembly are then turned upright. After shaking gently to start the water flowing, the intake tube is inserted in the support bracket and bolted to the fan housing.

It should be noted that the water reservoir of the psychrometric equipment described should always be completely filled with distilled water prior to placing the unit in a heated air stream. If the reservoir is not filled, heat will cause expansion of the entrapped air, which will in turn force the water remaining in the reservoir out through the wet-bulb well. Such a condition will result in excessive water flow over the wet bulb and an incorrect wet-bulb temperature.

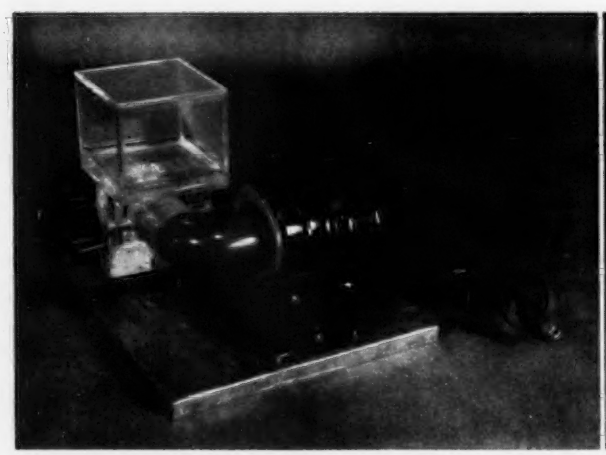
The wet-bulb assemblies described differ from those

(Continued on page 197)

Paper prepared expressly for AGRICULTURAL ENGINEERING, based on work done cooperatively by the farm buildings section, Agricultural Engineering Research Branch (ARS), U.S. Department of Agriculture, and Agricultural Engineering Department, College Experiment Station, University of Georgia.

The authors—B. C. HAYNES, JR. and L. L. SMITH—are, respectively, associate agricultural engineer, agricultural engineering research branch (ARS), and associate agricultural engineer, transportation and facilities branch (AMS), U.S. Department of Agriculture.

*Henderson, S. M. A constant-feed all-temperature wet-bulb, AGRICULTURAL ENGINEERING, vol. 33, p. 644, October, 1952.



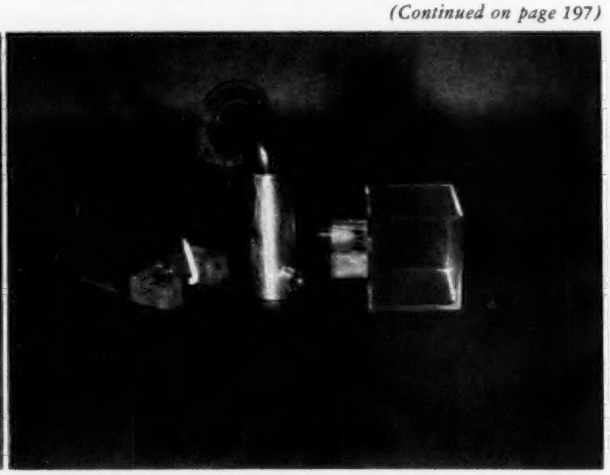


Fig. 1 *(Left)* Complete psychrometric unit showing method of mounting the blower and intake tube • Fig. 2 *(Right)* View of wet-bulb assembly disassembled from intake tube

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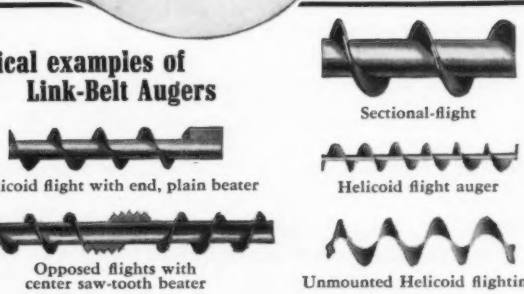

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NEWS SECTION

Colwick New Chairman Southeast Section

REX F. COLWICK, agricultural engineer and correlator of the USDA Regional Cotton Mechanization Project, was elected the new chairman of the Southeast Section of the American Society of Agricultural Engineers at the Section meeting held at Louisville, Ky. last month. He succeeds Harold D. White of the agricultural engineering staff of the University of Georgia.

Two new vice-chairmen of the Section were elected at the meeting, Sidney C. Smith, regional product specialist, International Harvester Co. and Thomas V. Wilson, agricultural engineer, North Carolina State College.

R. P. Kay, field representative, Douglas Fir Plywood Assn., was elected the new secretary of the Section.

A highlight of the Section program was the address by ASAE President George B. Nutt, head, agricultural engineering department, Clemson Agricultural College. Mr. Nutt discussed primarily the current agricultural engineering student enrollment situation, in relation to potential enrollment and the present and prospective future demand for agricultural engineers.

C. H. Jefferson, agricultural consultant, Farm Institute, Reynolds Metals Co., headed local arrangements for the meeting which included a Section dinner provided through the courtesy of local organizations of the Ford Motor Co., International Harvester Co., Minneapolis-Moline Co., Standard Oil Co., and Reynolds Metals Co.

Frost New Chairman of P. C. Section

K. R. FROST, assistant professor of agricultural engineering and assistant agricultural engineer in the agricultural experiment station, University of Arizona, Tucson, was elected the new chairman of the Pacific Coast Section of the American Society of Agricultural Engineers at the annual meeting of the Section held January 28 and 29 on the campus of Fresno State College at Fresno, Calif. He succeeds Ben L. Hagglund, sales manager, Caterpillar Tractor Co., San Leandro, Calif.

The newly elected vice-chairman of the Section is Matthew E. Hamilton, chief engineer of the Stockton Plant of J. I. Case Co., Stockton, Calif.

The long-time secretary-treasurer of the Section, Walter W. Weir, drainage engineer emeritus, department of soils, University of California, Berkeley, was re-elected to that office.

The elected member of the executive committee of the Section is Austin A. Armer, agricultural engineer, The Spreckels Sugar Company.

Watershed Protection on Washington Program

PLANNING for watershed protection and flood prevention was the subject of a talk by Carl D. Brown, director, planning division, Soil Conservation Service, USDA, at one of the regularly scheduled meetings of the Washington (D. C.) Section of the American Society of Agricultural Engineers on February 11. In his talk Mr. Brown discussed the new upstream watershed protection responsibilities of the U. S. Department of Agriculture under Public Law 566.

John G. Sutton, drainage engineer, Soil Conservation Service, and a past-chairman of the ASAE Soil and Water Division, presided as chairman of the meeting.

ASAE Meetings Calendar

March 18—OHIO SECTION, Republic Steel Corp., Canton, Ohio

April 1 and 2—MID-CENTRAL SECTION, Hotel Robideaux, St. Joseph, Mo.

April 8 and 9—ROCKY MOUNTAIN SECTION, Utah State Agricultural College, Logan

April 8 and 9—ALABAMA SECTION, Dadeville, Ala.

April 14 and 15—PENNSYLVANIA SECTION, Penn. State University, State College

April 22 — MICHIGAN SECTION, General Motors Technical Center, 15 Mile Road (East of Mound), Detroit

April 22 — IOWA-ILLINOIS SECTION, Hotel Blackhawk, Davenport, Iowa

April 22 and 23—FLORIDA SECTION, University of Florida, Gainesville

May 1 and 2—SOUTHWEST SECTION, Arlington Hotel, Hot Springs, Ark.

May 6—OHIO SECTION, Ives Hall, Ohio State University, Columbus

June 12 to 15—48th ANNUAL MEETING, University of Illinois, Urbana

August 22-24—NORTH ATLANTIC SECTION, University of Connecticut, Storrs

December 12 to 14 — WINTER MEETING, Edgewater Beach Hotel, Chicago

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.

Arid Lands Meetings

THE Southwestern and Rocky Mountain Division of the American Association for the Advancement of Science is sponsoring an arid lands symposium and conference to be held at the University of New Mexico and New Mexico Institute of Mining and Technology, April 26 to May 4, 1955.

The meetings will open April 26 at the University of New Mexico, Albuquerque, with a symposium on the future of arid lands. Two symposiums have been arranged for April 27, one on variability and predictability of water supply in arid regions and the other on better use of present resources. The two symposiums on April 28 will feature two main subjects, namely, prospects for additional water sources and better adaptation of plants and animals to arid conditions. April 29 will be devoted to sessions of 13 discussion groups on various subjects.

April 30 and May 1 of the meetings will be devoted to a field trip, and May 2 to 4 will be given over to a 3-day conference to be held at the New Mexico Institute of Mining and Technology, Socorro, when an opportunity will be offered for groups of experts to exchange views and ideas and to work out ways for the various sciences represented at the conference to pool their efforts in the solving of arid lands problems.

Further information concerning the program may be obtained from the American Association for the Advancement of Science, 1515 Massachusetts Ave., N. W., Washington 5, D. C.

Looking Ahead to 1958

THE Council of the American Society of Agricultural Engineers having last year voted to hold the 1958 Annual Meeting of the Society in California, the Society's Pacific Coast Section at its last meeting in January appointed a local arrangements committee to start planning for the 1958 meeting, which will consist of C. T. Rasmussen (chairman), J. R. Tavernetti, M. R. Huberty and B. L. Hagglund. This committee will work in close cooperation with the Section executive committee in laying plans for the meeting.

NEWS OF ASAE MEMBERS

Harold E. Pinches has resigned as director of research of the American Kitchens Division, Avco Mfg. Corp., to accept the position of assistant director, farm and land management research, Agricultural Research Service, U.S. Department of Agriculture, Washington, D. C.

George G. McCutcheon, who has been in product research work for the New Holland Machine Division of The Sperry Corp., recently resigned to accept employment in the product planning and programming office of the Tractor and Implement Division, Ford Motor Co., Birmingham, Mich.

Richard L. Mortimer recently joined the engineering organization of New Holland Machine Division, The Sperry Corp., New Holland, Pa. He was formerly with S. M. Langston Co., Camden, N. J.

Irwin G. North, Jr., has resigned as a design engineer of the John Deere Killefer Co. to accept employment with the Anaconda Wire & Cable Co., Orange, Calif.

Simon M. Radford recently terminated his employment as service manager of Union Tractor and Equipment Co., Ltd., Calgary, Alberta, Canada, and following a trip to Europe where he will visit most of the agricultural engineering institutions in England, France, Belgium, and Holland, especially the NIAE in England, he will return to the United States to accept employment in the engineering department of Caterpillar Tractor Co., Peoria, Ill.

Charles W. Suggs, who has been employed since last October as research instructor in the agricultural engineering department at North Carolina State College, will receive his M.S. degree from that institution in June of this year, following which he will devote full time to research work on tobacco mechanization with emphasis on the harvesting aspects. He is familiar with the crop having served as superintendent of one of the tobacco experiment station farms in North Carolina following his graduation from NCSC.

Mardis R. Warner, a 1950 graduate in both agriculture and agricultural engineering from Ohio State University and for the past five years serving as extension agricultural engineer at the University of Maine, has resigned his position to accept appointment as extension agricultural engineer at the University of Maryland, College Park.

Richard E. Griffin for the next two years will be working under contract with the Utah State Agricultural College on a Point IV contract in Iran, where he will be engaged in irrigation and other agricultural engineering work.

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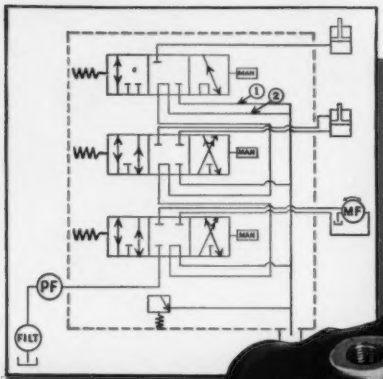

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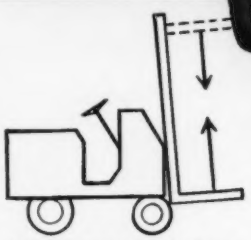

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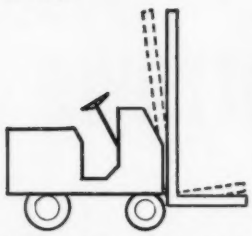
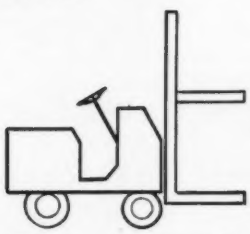


Tilt the platform forward or back quickly and without shock while standing still or in motion.



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Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Baker, Peter M. — Postgraduate student in agricultural engineering, King's College, Newcastle-on-Tyne 3, England. (Mail) 11 Woodlands Park Villas

Britt, James E.—Manager, tractor div., K. M. Biggs, Inc., Lumberton, N. C. (Mail) 28 Magnolia Ct.

Burman, Robert D.—Agricultural engineer, Bureau of Land Management, USDI, Worland, Wyo. (Mail) 520 N. 9th

Claas, Helmut F. — Engineer, Gebr. Claas Maschinenfabrik. (Mail) Harsewinkel, Westfalen, Germany

Clendenin, Wilbur H. — Product designer, International Harvester Co. (Mail) 1831 Kenilworth, Berwyn, Ill.

Coles, Errol D.—Extension agricultural officer, Department of Agriculture. (Mail) P.O. Tzaneen, N. Transvaal, South Africa

Coriell, Robert L. — Design engineer, The Oliver Corp., 423 E. Michigan Ave., Battle Creek, Mich.

Dias, Galloluwege R. W. — Assistant to chief agricultural engineer, Agricultural Engineering Div., Peradeniya, Ceylon

Dorwin, John J. — Chief engineer, The Oliver Corp., 108 So. McCamley St., Battle Creek, Mich.

Driskell, E. D.—Field representative and development engineer, Southeastern Liquid Fertilizer Co., Albany, Ga. (Mail) 531 8th Ave.

Durrstein, Robert L.—Design engineer, The Oliver Corp., 423 E. Michigan Ave., Battle Creek, Mich.

Edwards, Burton L. — Aircraft maintenance officer, USAF. (Mail) Grant, Mich.

Ellen, James T. — Electrification advisor, Halifax Electric Membership Corp., (Mail) Enfield, N. C.

Everett, C. V.—Chief engineer, harvester div., Massey-Harris-Ferguson, Inc., Racine, Wis. (Mail) 3414 Osborn Blvd.

Ffitch, Bruce J. — Junior engineer, John Deere Des Moines Works, Des Moines, Iowa. (Mail) Apt. 26B, 3523 University Ave.

Fokes, James C.—Sales manager, The Doolittle Tractor & Implement Co., Charlotte, N. C. (Mail) PO Box 1192

Fricke, Thomas J. — Consulting engineer, 730 Porter St., Stuttgart, Ark.

Gordon, Robert H. — District manager of northern California, The Fafnir Bearing Co., 255 Loomis St., San Francisco, Calif.

Harrell, Grover L. — Electrification advisor and right-of-way engineer, The Roanoke Electric Membership Corp., Rich Square, N. C. (Mail) PO Box 85

Hasty, William H.—Owner, Maxton Service Co., Maxton, N. C. (Mail) Box 686

Keays, William L. — Sales engineer, Bearings Co. of America. (Mail) 1518 5th Ave., Moline, Ill.

Konneker, Peter A. — Assistant in agricultural engineering, University of Illinois. (Mail) RR 5, Carlinville, Ill.

Mather, Thomas W.—Regional product engineer, Huck Manufacturing Co. (Mail) 483 E. Illinois Road, Lake Forest, Ill.

Midgett, James A. — Vice-president and general manager, Thompson Irrigation Co., Inc., Kinston, N. C. (Mail) Box 309

(Continued on page 198)

RESEARCH NOTES

Brief news notes and reports on research activities of special agricultural-engineering interest are invited for publication under this heading. These may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Michigan.

USDA Research Activities

Fiber for Cordage Research efforts in developing production equipment for sansevieria, a substitute fiber for abaca used in making rope, is being materially aided by a 50-acre plot in Palm Beach County, Florida, made available by the county commission, for the pilot planting of this crop over a 5-year period. Ready availability of this crop is expected to speed up the research work being done by the Agricultural Engineering Research Branch's Mechanical Preparation and Conditioning Section on harvesting, leaf cutting, transplanting, defibering equipment and operations.

Cotton Bulletin James R. Tavernetti, agricultural engineer, California Agricultural Experiment Station, Davis, and H. F. Miller, agricultural engineer, AERB's Farm Machinery Section, Beltsville, Md., are coauthors of a recently issued California bulletin (No. 474) entitled "Studies on Mechanization of Cotton Farming in California."

In general, the bulletin reports on mechanization studies which began in California in 1946 and were conducted in detail since 1948. Included is information covering experimental research in high and low-bed planting, use of seed-press wheels, plant populations, weed control, topping defoliation, and mechanical cotton picking.

Commercial Tungnut Harvester R. E. Jesek, Farm Machinery Section, AERB, stationed at Bogalusa, La., and W. W. Kilby, South Mississippi Branch Experiment Station, Poplarville, Miss., have recently tested the efficiency of a commercially produced experimental tungnut harvester under actual harvest conditions. The machine was constructed by Edgar Jones at Evansville, Ind., based on other experimental machines and principles developed over the past several years by the project. It operated on a custom basis during the 1954 harvest season. Tests indicated the feasibility of the mechanical harvesting of tungnuts on large acreages. They proved, however, that growers interested in the mechanical harvesting of their crops, should prepare the land by levelling in order to obtain the highest efficiency of mechanized harvesting.

Engineers Study "Hazel" J. R. Dodge and E. C. Molander, Farm Buildings Section, AERB, cooperated with University of Maryland agricultural engineers A.V. Krewatch and P. N. Winn, Jr., in a survey of the heavy damage done by the October hurricane to farm service buildings in Maryland. A study was made of the causes of the failure of the construction in many buildings. The study was the basis of a "fact sheet" issued by the University of Maryland Agricultural Extension Service in December, and findings and construction suggestions in greater detail will be included in a bulletin being prepared by the Farm Buildings Section.

In addition, hurricane damage and ways to prevent it was the subject of a USDA TV short in which the Farm Buildings Section and University of Maryland agricultural engineers cooperated.

Psychroenergetic Laboratory Studies Three breeds of beef calves are on test at the psychroenergetic laboratory at Columbia, Mo., at the present time to check the growth and development made by each breed under the controlled conditions that can be provided in the laboratory. R. G. Yeck, Farm Buildings Section, is in charge of the engineering phase of the work which is in cooperation with the Missouri Agricultural Experiment Station. The tests, to determine how growth and development is affected by temperature, are being made with Shorthorn, Brahma, and Santa Gertrudis calves.

Effects of Temperature on Egg Production Wilber O. Wilson, physiologist, California Agricultural Experiment Station, Davis, recently completed a 6 months stay at Beltsville, Md., out of his sabbatical leave, to study the effect on egg production and the physiological reaction of laying hens under varying temperatures. H. L. Garver and Hajime Ota, Farm Buildings Section engineers, and the poultry specialists at Beltsville Research Center cooperated with Dr. Wilson on the project. The poultry calorimeter at the Research Center was used in the experiments.

Light Traps for Florida Thirteen light traps have been set up at seven locations in Florida by Farm Electrification Section engineers, J. M. Stanley, Blacksburg, Va., and John G. Taylor, Lafayette, Ind., in cooperation with other USDA agencies and the Florida State Plant Board to check on the emergence and presence of important insect pests and the efficiency of the traps.

The traps have been located strategically throughout the length of the state in an effort to catch specimens of the insects as they emerge seasonally at the various locations. The objective is to check on the development and movement of various insect pests, such as the cotton bollworm, the army worm, and several cutworms so that proper control measures can be taken.

In addition, Farm Electrification Section engineers will check on the efficiency of the traps. Those in use this year have been modified and improved for insect survey purposes. The "black light" has been retained in the new models, but the wattage has been reduced from 30 to 15 w and physical changes have been made in the traps in order to keep the trapped insects in better condition for examination by entomologists.

Plans are to set up traps in various locations in Georgia, South Carolina, North Carolina, Alabama, Mississippi, Texas, Arkansas, Missouri and Kansas as insect emergence is expected seasonally in these states. Arrangements are being made with state agricultural engineering departments where possible to cooperate in observing operation of these traps throughout the season.

Psychrometric Equipment

(Continued from page 192)

designed by Henderson for two reasons:

1 It is extremely difficult to fill closed glass-tube assemblies and be certain of good thermal contact with the enclosed thermocouple. The construction used by the authors in which the thermocouple junction was soldered directly to the brass tip assures excellent conduction.

2 The plastic wet-bulb stem provides some thermal insulation of the brass sensing tip from the high temperature of the water in the wet-bulb well.

(EDITOR'S NOTE: Detailed construction drawings may be procured by writing the authors.)

Michigan Combine in California

TO THE EDITOR:

I HAVE noted that Michigan State College is making preparations to celebrate its Centennial this year, and this suggests to me that you might be interested in a book I am now doing on John M. Horner, California's "first farmer."

It was Horner who arranged to have the Michigan combined harvester sent to California in 1853 to harvest 600 acres on his and neighbors' wheat fields near Mission San Jose in 1854, to start us on our 101-year continuous use and development of that revolution in agriculture. It set the tempo for our agriculture ever since and cut costs of harvesting grain crops practically in half, from $3.00 to $1.75 an acre, reported by one writer in 1890.

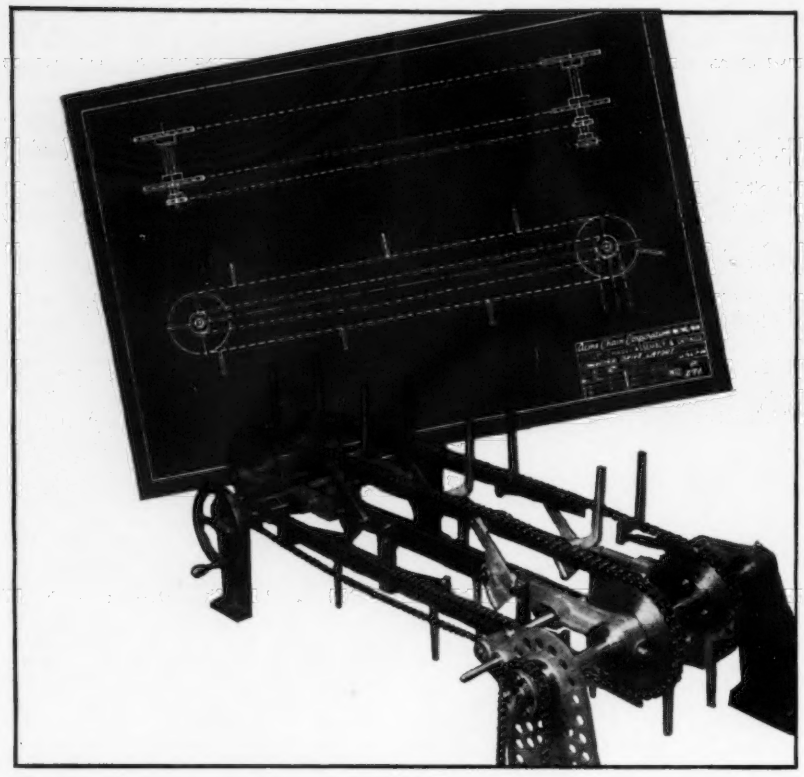
But the man who sent his son and partner out to operate this Hiram Moore harvester was A. Y. Moore, the president of the Michigan Agricultural Society, who had called his board together and picked out the site for Michigan Agricultural College on orders of the Michigan legislature.

A. Y. Moore moved to California and wrote several letters to the *Pacific Rural Press* and his children on his life and the Hiram Moore machine. George Leland, his partner, who brought the machine from Michigan to California for that first combine harvest in 1854, also seems to have remained in California. At least, a news item in an Oakland newspaper at the end of the 1860 season reports that he had operated a combined reaper and thresher pulled by 20 horses in the same area as the original Hiram Moore machine was used six years earlier. Since A. Y. Moore's letter to the *Pacific Rural Press* in 1886 says the first machine was destroyed by fire from an overheated bearing in 1856, it is clear that Leland built at least one more combine of the size of the original. Possibly he duplicated that first machine that A. Y. Moore had built and used for several seasons in Michigan before sending it to California. Moore's letters state that he had first operated two of the machines Hiram Moore had built at Rochester, N. Y., at Hall's thresher factory. A. Y. Moore had then built a copy of this machine for himself and operated it a few seasons in the late '40's and early '50's before sending it to California with his son and partner.

I will try to get you a copy of my chapter on the use of the combine by Horner when the manuscript for my book is completed. Stanford and Oklahoma university presses, Claxton and another or two all want a chance to look it over. The big problem is to get an artist who can take the Michigan combine as built and used by Hiram Moore in Michigan and try to adapt it as used here in California in 1854 when 20 horses with one driver replaced 16 horses and 8 drivers in Michigan.

I finally found the Michigan picture with Hiram in his high hat. It was published in *Farm Implement News* about 10 or 12 years ago with a review of the combines up to modern times. As Horner put the horses behind to push instead of pull when he began building combines in 1859, I want to get an artist to show that too, though no photos have turned up in my 25 years of search out here. Of course I had given those areas over in Michigan and Wisconsin a thorough going over, when I was located at Peoria as Caterpillar's news editor in 1930 to 1933.

Walnut Creek, Calif. F. HAL HIGGINS



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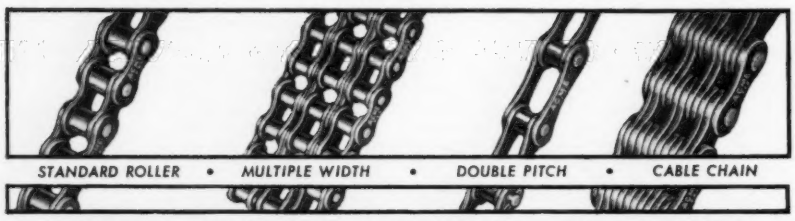
ACME engineers are roller chain experts . . . continually abreast with the advances in roller chain application. Whatever your problem, involving chain, call for the voluntary service of an ACME engineer. *Write or phone JEfferson 2-9458.*



RUGGED PRECISION CHAIN for EVERY NEED

Write Dept. 9S for new illustrated 76 page catalog on use and application of roller chains and sprockets.

Acme Chain Corporation
HOLYOKE
MASSACHUSETTS

Applicants for Membership

(Continued from page 196)

Miller, Wayne L. — Design engineer, The Oliver Corp., Battle Creek, Mich. (Mail) 317 Pleasant View Dr.

Morris, Carl F.—Research engineer, Butler Manufacturing Co. (Mail) 7528 Colonial Drive, Overland Park, Kans.

Mukerji, T. K.—Assistant agricultural engineer, 69/B Ballygunge Place, Calcutta (19), India

Ordoveza, Juan L.—Assistant instructor in agricultural engineering, Cornell University, Ithaca, N. Y.

Peterson, Merton W.—Assistant chief engineer, tillage div., Massey-Harris- Ferguson, Inc. (Mail) 130 So. Prairie St., Whitewater, Wis.

Rivero, Jose A. — Engineer and assistant manager, Central Manuelita Compania Azucarera, S. A., Manuelita, L. V., Cuba

Roeder, Dale—Chief engineer, Tractor and Implement Div., Ford Motor Co., 2500 E. Maple Road, Birmingham, Mich.

Rogers, Ralph G. — Works manager, The Oliver Corp. (Mail) 1055 Cobb Blvd., Kankakee, Ill.

Smith, Robert M.—Project engineer, implement engineering dept., Tractor and Implement Div., Ford Motor Co. (Mail) 8917 Petoskey, Detroit 4, Mich.

Steiger, Paul E.—Farm service dept., New York State Electric & Gas Corp., Binghamton, N. Y.

Stephens, Connor L.—Instructor in agricultural engineering, Long Island Agricultural & Technical Institute, Farmingdale, N. Y.

Stevens, Albert C. — Medical laboratory technician, U.S. Army, Medical Unit Det. 4, Station Comp. SU3442, Ft. McPherson, Ga.

Stine, Victor L. — Manager and sales engineer, Indiana Farm Service, Goshen, Ind. (Mail) 411 Sunset Blvd.

Tazelaar, Jack J.—Partner, Wonder Building of Western Michigan. (Mail) 303 Fuller Ave. N.E., Grand Rapids, Mich.

Thompson, Hayden Jr. — Self-employed farmer and rancher, Dumas Route, Hartley, Tex.

Troutman, Ray K.—1st Lt., installations engineer, USAF. (Mail) 24178-A, 6464th Air Base Squadron, APO 963, San Francisco, Calif.

Tsuchiya, William S. — Design engineer, John Deere Killefer Co., Los Angeles 33, Calif. (Mail) 422 So. Boyle Ave.

Twist, Basil R.—Partner and plant superintendent, Towner Manufacturing Co., Santa Ana, Calif. (Mail) PO Box 264

Villacres, Richard A.—Regional product engineer, Huck Manufacturing Co. (Mail) 5500 11th Ave., South, Minneapolis 17, Minn.

Waterhouse, W. I.—Special representative, sales development div., Caterpillar Tractor Co., Peoria, Ill.

Whitesides, Jack C.—Instructor in agricultural engineering, Clemson Agricultural College, Clemson, S. C. (Mail) Box 417

Willman, James L. — Field representative, American Zinc Institute, 324 Ferry St., Lafayette, Ind.

Wiltsey, Howard E. — Senior product engineer, J. I. Case Co., Racine, Wis. (Mail) 4304 Olive St.

Wolfe, Chester G. — Product designer, International Harvester Co. (Mail) 1927 36th St., Moline, Ill.

(Continued on page 200)

Now, its the NEW

NEW IDEA No. 17

NEW IDEA

FULL-YEAR SERVICE GUARANTEE

Squarely in back of our products

in the

Name and Reputation of

THE NEW IDEA FARM EQUIPMENT COMPANY

OUR INTEREST IN YOU does not cease when this manure spreader has been delivered and paid for. As builders of quality farm equipment for well over fifty years, we know how important this purchase is to you and your farming operations.

THEREFORE, IF AT ANY TIME during the first full year after purchase this manure spreader fails to give satisfaction, bring the matter to the attention of your New Idea dealer.

WE GUARANTEE this No. 17 manure spreader for one full year from purchase to be of sound material and workmanship. It is guaranteed capable of performing the work for which it is intended, when properly set up and operated under normal use and service according to the instruction Manual furnished you. Any parts which are shown to be defective during the above period (except tires, tubes, rims, and lubrication fittings, which are guaranteed by their manufacturers) will be exchanged free of charge, F.I.B. factory or branch.

NEW IDEA FARM EQUIPMENT COMPANY
Division AVCO Distributing Corporation

Corry W. Stoop
Vice President and General Manager

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The GUARANTEED spreader with the "Blue Ribbon" features

GUARANTEED . . . for every No. 17 spreader purchased and registered with a franchised NEW IDEA dealer, the owner receives a guarantee that covers repair part replacements for one full year.

- **Slanted Rear Arch.** The heavy rear arch is lower and permits easier loading. Cannot interfere with high spots on the load.
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- **Steel Flares** run full length of bed—give added protection when loading and strengthen box.
- **Gusset plate reinforcing** from frame to box gives strongest NEW IDEA box ever.
- **Effective shielding**—all working parts protected by higher and wider shields.

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Division AVCO Distributing Corporation COLDWATER, OHIO,

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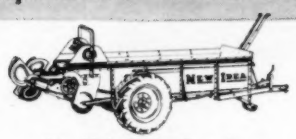
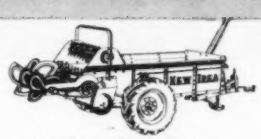
95 bushel capacity

4 other great Spreaders make the NEW IDEA line the world's greatest!

No. 10-A, 75 Bu. Capacity



No. 12-A, 90 Bu. Capacity



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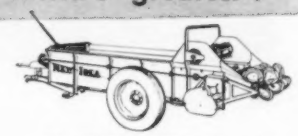


No. 15 PTO, 120 Bu. Capacity

Applicants for Membership

(Continued from page 198)

Transfer of Membership Grade

Becker, Clarence F.—Assistant professor of agricultural engineering, University of Wyoming, Laramie, Wyo. (Mail) 2010 Thornburg. (Associate Member to Member)

Bentz, Erwin J. H.—Research staff engineer, Caterpillar Tractor Co. (Mail) 500 W. Jefferson, Washington, Ill. (Associate Member to Member)

Bondurant, James A.—Assistant in agricultural engineering, University of Nebraska, 201 Agricultural Engineering Bldg., Lincoln 1, Nebr. (Associate Member to Member)

Butt, J. L.—Associate agricultural engineer, Alabama Polytechnic Institute, Auburn, Ala. (Associate Member to Member)

Erie, Leonard J.—Irrigation engineer, Agricultural Research Service (USDA), Phoenix, Ariz. (Mail) Post Office Bldg., Room 24. (Associate Member to Member)

Hassler, Francis J.—Associate professor in agricultural engineering, North Carolina State College, Raleigh, N. C. (Associate Member to Member)

Holliday, John W.—Partner and engineer, Holliday Construction Co., Greenville, Ga. (Mail) Box 116. (Associate Member to Member)

Jahr, Everett C.—Agricultural engineer (SCS), USDA, 328 Lincoln Ave., Salinas, Calif. (Affiliate to Associate Member)

Johnson, E. R.—Farm manager, International Harvester Co., Hinsdale, Ill. (Mail) S. County Line Rd. (Associate Member to Member)

Johnson, Otto E.—Product engineer, International Harvester Co., Canton, Ill. (Mail) 225 Haffner Blvd. (Associate Member to Member)

Lake, Shirlee M.—Technical manual writer, J. I. Case Co. (Mail) 7325 24th Ave., Kenosha, Wis. (Affiliate to Associate Member)

Lorenzen, Robert T.—Graduate student in agricultural engineering, University of California, Davis, Calif. (Associate Member to Member)

Magee, Allan—Agricultural research officer, Canada Department of Agriculture. (Mail) Agricultural Engineering Bldg., Central Experimental Farm, Ottawa, Ont., Canada. (Associate Member to Member)

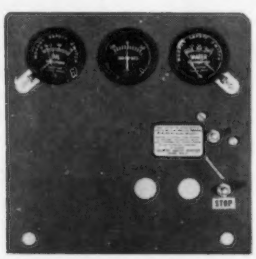
Ricketts, Ralph L.—Extension agricultural engineer, University of Missouri, Columbia, Mo. (Mail) 109 N. Greenwood. (Associate Member to Member)

Snell, A. W.—Associate professor in agricultural engineering, Clemson Agricultural College, Clemson, S. C. (Associate Member to Member)

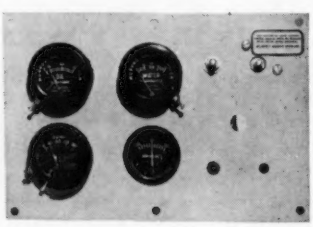
Wheary, C. D.—Associate extension agricultural engineer, Virginia Polytechnic Institute, Blacksburg, Va. (Associate Member to Member)

Protect Your Valuable Irrigation Engines And Tractors With MURPHY SAFETY SWITCHES

Complete panels or individual switches. Easily installed. Proved reliable by years of continuous service under the most rugged operating conditions.



WH-B — Complete instrument for Plains Type irrigation engines. Space on panel for voltage regulator, starter button, throttle and choke.
For Diesel Engines: Model WD-300



MODEL WH-5452 — For sprinkler irrigation engine and pump protection. Complete unit protection in easily mounted steel panel. Equipped with water temperature and lube oil pressure gauge-switches, loss of prime pump switch, ammeter and magnetic ignition switch. Throttle, starter, and choke mounting holes.

TRACTORS NEED PROTECTION TOO

MODEL W-275 — Features our new automatic lube oil disconnect switch. Pushbutton sets lockout. Normal lube oil pressure automatically resets switch when engine is started. Cast tenzaloy panel provides a neat, easily mounted panel.

SAFETY SWITCH-GAUGES for mounting in original equipment instrument holes. Model O-27 low lube oil protection. Model SR-21 high temperature protection.

For Battery Ignition Tractors: O-27 Oil Pressure Switch-Gauge. SR-21 - Temperature Switch-Gauge, #117 Magnet Snap Switch on mounting bracket.

MODEL WU-B — Universal mounting panel for battery ignition engines. Oil pressure and water temperature safety switches and #117 magnetic ignition switch. 13/16" hole for starter button.

Safety Switch Panels for Diesel Tractors and Engines Available

Wherever there is irrigation, you will find a Murphy Dealer with a stock of switches and parts, ready to offer you service.

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NEW BOOKS

How to Use Portable Power Tools, by Maurice Reid. Paper, 200 pages, 5½x8 inches. Illustrated and indexed. Porter-Cable Co., 55 Exchange St., Syracuse 8, N. Y. $1.50.

The book was designed as a practical manual for home craftsmen, vocational students and farmers. It gives step-by-step instructions on the uses of all standard portable electric tools, newly developed machines, and numerous attachments that do just about every job around the house, grounds and outbuildings. It has 180 photographs to teach all the tricks of trade, enabling the user to turn out skillful work many times faster and with less fatigue than by ordinary methods. The publisher calls it the basic guide for all who like to work with tools.

NEW BULLETINS

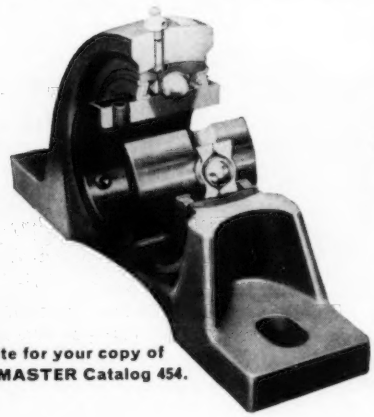
Concrete Tile for Farm Drainage. Portland Cement Association (33 W. Grand Ave., Chicago 10, Ill.). Practical information on the subject condensed into an 8-page illustrated leaflet.

Effectiveness of the L-Shaped Fence Staple, by E. George Stern. Virginia Polytechnic Institute (Blacksburg) Wood Research Laboratory Bulletin No. 17 (October 1954). Results of one-year accelerated exposure tests at VPI, and exposure tests at Duke University, and U and L-shaped staples of varying lengths in green, partly dried and creosoted posts show comparable holding powers when first driven, with serious drop off in holding power of the U-shaped staple beginning within the first week, and generally sustained or increased holding power in the case of the L-shaped staple with annular threads. L-shaped staples with sheared points are indicated as easier to drive, while those with diamond points showed somewhat greater advantage in sustained holding power.

(Continued on page 206)

Idle machinery costs the farmer Time and Money—

Write for your copy of SEALMASTER Catalog 454.



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BALL BEARING UNITS
"KEEP HIM ROLLING"

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Despite the progress made in farm equipment during the past decade many machinery manufacturers still fail to take advantage of the benefits of anti-friction sealed bearings.

Often shafts still turn in simple sleeve bearings or even wooden blocks, resulting in inefficient power transmission and making it easy for dust and dirt to cause complete breakdowns—usually occuring at the most critical times.

Machinery manufacturers, implement dealers and farmers once acquainted with the exclusive advantages of SEALMASTER Ball Bearing Units, not only insist on their use in new machinery but convert to SEALMASTER on existing equipment. In addition to tremendous savings in power consumption, lubrication and maintenance, SEALMASTER's self-aligning feature practically eliminates vibration—one of the primary causes of part failure.

You will want more information on "The Advantages of SEALMASTER Ball Bearing Units in Farm Machinery". Write today.

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NEW PRODUCTS CATALOGS

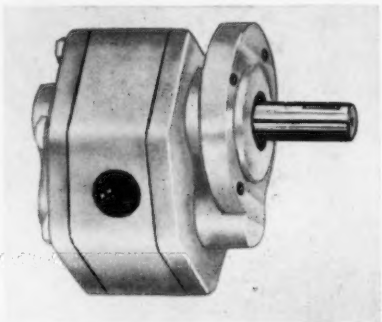
A New Diesel Tractor

The Oliver Corp., 400 W. Madison St., Chicago 6, Ill., announces what it calls a totally new tractor, the Oliver Super 99 GM diesel, which is the sixth in a series of new tractors introduced by the company during the past six months. It is classed as a 5-6 plow tractor, and the tractor is powered by a 2-cycle General Motors diesel engine, a 100 percent diesel which starts on diesel fuel alone; no auxiliary engine or special fuel is needed. According to the manufacturer, the 2-cycle principle provides an exceptionally smooth flow of power, and the engine responds instantly and will not slow down under load changes.

Other features of the tractor include a 6-forward-speed transmission, a roomy flat operator's platform, rubber spring seat, double-disk differential brakes, a recirculating ball-type steering gear. Special units include an independently controlled power take-off and a 3-way hydraulic system that permits adjustment of working depth from the tractor seat.

Hydraulic Motors

Wisconsin Hydraulics, Inc., 3165 North 30th St., Milwaukee 16, Wis., has announced a new line of hydraulic motors. These gear-type motors develop from 0.10 to 7.5 hp and are rated for 1000 psi continuous duty. These lightweight reversible motors are available in a variety of mountings and portings, they are designed and engineered for farm and road-building machinery and truck-mounted equipment.



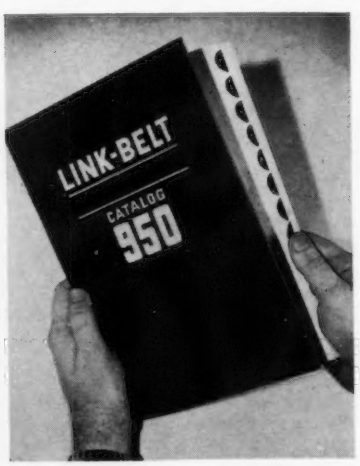
"Let Your Diesel Live"

"Let Your Diesel Live" is the title of a new booklet published by Caterpillar Tractor Co., Peoria, Ill., copies of which may be obtained by writing direct to the company and mentioning Form No. 12440. The development of more efficient lubricating oils to get longer and more reliable service from diesel engines is related in this booklet which contains the story of lubricating oils and how they affect owners of Caterpillar diesel engines.

Power Transmission and Conveying Equipment Catalog

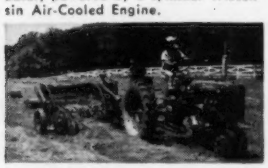
Link-Belt Co., Dept. PR, 307 North Michigan Ave., Chicago 1, Ill., will send on request to interested readers a copy of a 340-page standard products catalog (No. 950) covering its complete standard lines of power transmission and conveying equipment. This indexed book contains information for the engineer or layout man in selecting standard products for new installations or for replacements. It includes data on Link-Belt's complete line of chains for

(Continued on page 204)



CASE Model "130" automatic twine tie one-man pickup Baler, powered by 2-cyl. Wisconsin Air-Cooled Engine.

JOHN DEERE Model 14-T Twine-tie Baler, powered by 2-cylinder Wisconsin Air-Cooled Engine.



McCORMICK No. 45 one-man, family size twine-tie Baler, powered by 2-cylinder Wisconsin Engine.

MASSEY-HARRIS No. 1 Twine-tie Slicer Baler (52-inch pickup width) powered by 4-cylinder Wisconsin Engine.

MINNEAPOLIS-MOLINE Harvester "69" Combine powered by 4-cylinder Wisconsin Engine.

NEW HOLLAND Model 601 Forage Harvester (chops up to 22 tons of grass per hour), powered by 4-cylinder Wisconsin Engine.

The Best Farm Machines Use the Best POWER

WISCONSIN HEAVY-DUTY *Air-Cooled* ENGINES

It is a source of pride to us, as engine manufacturers, and, we believe, a source of satisfaction to users of farm power equipment, that the Great Names in the American Farm Implement Industry give their considered preference to Wisconsin Heavy-Duty Air-Cooled Engines.

The selection of built-in power units for many kinds of farm and orchard machinery calls for careful and thorough investigation of the engines that are specified as "original equipment". It also calls for the same kind of consideration in "measuring up" the engine builder . . . to make sure that both the *product* and the *producer* will meet the high standards of the great concerns who build most of the farm equipment you buy and use.

These farm equipment builders appreciate the value of such Wisconsin Engine features as heavy-duty design and construction to provide the rugged stamina needed in farm service; file-hard, self-cleaning tapered roller bearings at BOTH ends of the crankshaft for smooth running and greatest protection against bearing failure; high tension OUTSIDE Magneto equipped with Impulse Coupling for easy starting in any weather at low cranking speed; positive ignition and pump circulated lubrication . . . *plus* efficient, foolproof AIR-COOLING at all temperatures from sub-zero to 140° F., and Lugging Power that *hangs on* through the shock-load pinches.

You can't do better than to be guided by the good judgment of the farm and orchard equipment builders who specify "'Wisconsin Power" for their machines.

WISCONSIN MOTOR CORPORATION

World's Largest Builders of Heavy-Duty Air-Cooled Engines

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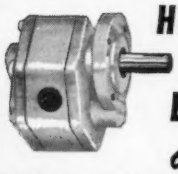
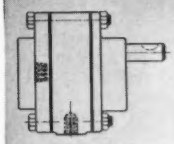
WISCONSIN HYDRAULICS MOTORS...

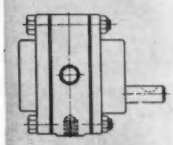


HIGH PERFORMANCE—
MORE RELIABLE—
EASY MOUNTING—
at lower cost!

VARIATIONS



END PORTS OR SIDE PORTS • FLANGE OR PAD MOUNT • SHAFT CLOSE OR FAR FROM PAD.



These rugged, gear-type motors are rated for 1000 p.s.i. continuous duty. Lightweight, compact and easy mounting, these precision manufactured motors are available in modifications for special installations. SM Series Motors have output capacity up to 8 H.P.

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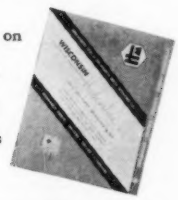
Write for File No. 101 on our standard line of hydraulic valves, motors, pumps, large diameter cylinders and valve and pump combinations. Special hydraulic systems engineered to your requirements.



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WISCONSIN Hydraulics, INC.
3165 N. THIRTIETH ST. MILWAUKEE 16, WIS.

Here is the nut that resists stress, wear and vibration

Extra holding power need not add to the cost of any assembly. Gripco Lock Nuts are of one-piece design—thus low in initial cost. Their faster application reduces production costs, their greater holding power reduces mechanical wear and failures, which means longer product life for greater customer satisfaction. The Gripco Lock Nut, with triangular depressions on its top, provides frictional resistance to vibration and permits repeated removal and reapplication. The locking action is produced by a simple, vertical thread deflection, inherent in the nut itself—the same design that has held threaded fasteners tighter for over 50 years. If stress, wear or vibration poses a fastening problem for your products, see how a Gripco Lock Nut can give you a tighter hold, longer wear. Impervious to oil or water. Write for samples and full particulars.

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Gripco Lock Nuts, New Gripco "Clinch" Nuts, Gripco Hi-Nuts, Gripco Pilot-Projection and Countersunk Weld Nuts with or without Gripco locking feature.

101

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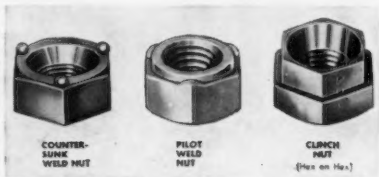
New Products and Catalogs

(Continued from page 202)

conveying and power transmission, ball and roller bearings, enclosed gear drives, clutches, gears, couplings, etc. One section lists components for screw conveyors, belt conveyors, bucket elevators, overhead trolley conveyors and Flexmount oscillating conveyors. Tables of preselected assemblies, concise capacity charts and dimension tables for all standard products are included.

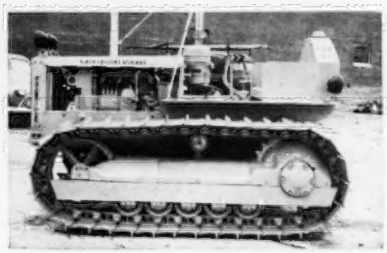
Stainless Steel Weld and Clinch Nuts

The Grip Nut Co., 310 S. Michigan Ave., Chicago 4, Ill., announces that it is now able to furnish both pilot-type and countersunk Gripco weld nuts in stainless steel, which are being made both with and without the Gripco self-locking feature. Gripco hexagon pilot clinch nuts are also available in stainless steel with and without the Gripco self-locking feature. Sizes at present available are 10-32 through ¼-inch, fine and coarse threads, and in the near future 5/16-inch and ⅜-inch sizes will be available in both fine and coarse threads.



Oscillating-Type Track Roller Frame

Caterpillar Tractor Co., Peoria, Ill., announces that it has made available, as an attachment for the Caterpillar D4 tractor, a new five-roller, oscillating-type track roller frame. The manufacturer states that installation of this track roller frame on the D4 will provide increased traction, greater flotation and better stability, particularly when the unit is operating on hilly terrain and in locations where soil conditions are soft or unstable.



A tractor equipped with the five-roller track frame requires a 34-section track in place of the 31-section track included on the standard four-roller machine. If large idlers are used, a 35-section track may be installed. Light-type roller guards are available as attachments for use with the five-roller track frame.

Automatic Twine-Tie Baler

The Tractor and Implement Div., Ford Motor Co., Birmingham, Mich., announces the new Ford 250 automatic twine-tie hay baler designed for one-man operation and employing sweep-fork feed. The machine has a capacity of four bales a minute and will be available in three models—engine driven with or without starter and power take-off.

The baler is designed for complete pick-up, with curved fingers for cleaner pickup of the windrow. A rubber-tired gage wheel maintains the proper relation of pickup fingers to the ground. The power-driven pickup provides for better control and more uniform feeding.

All three models of the baler weigh less than 3,000 lb. The overall width is 8 ft 5 inches, and the short length is 14 feet and 2 inches. Bale lengths are 36 or 42 inches and an average bale weighs approximately 60 lb. A bale counter is standard equipment. Engine-driven models are powered by a Wisconsin air-cooled, two-cylinder, 15-hp engine.

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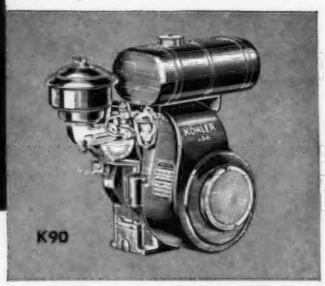

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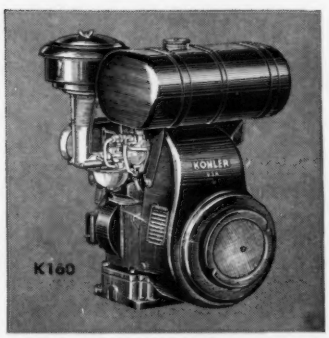

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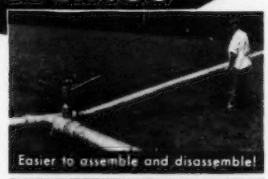

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NEW BULLETINS

(Continued from page 200)

An Evaluation of the Phase Converter-Three-Phase Motor, by Kenneth A. Harkness and John W. Hooper. Kansas Engineering Experiment Station (Manhattan) Circular No. 8 (July 1954). Presents advantages and disadvantages in comparison with capacitor start, capacitor run motors, with illustrative characteristic curves.

Fastening of Gypsum Wallboard with Threaded Nails, by E. Geo. Stern. Virginia Polytechnic Institute Wood Research Laboratory (Blacksburg) Bulletin No. 15 (June, 1954). Use instructions and data on immediate and delayed withdrawal resistance.

Effectiveness of Underlayment Nails, by E. George Stern. Virginia Polytechnic Institute (Blacksburg) Wood Research Laboratory Bulletin No. 18 (December 1954). This is a report of further tests on nails for fastening ½-inch thick plywood underlayment. It indicates that commercially available threaded-shank nails are considerably superior to plain shank nails commonly used for this purpose. The withdrawal resistance is materially increased, with resulting decreases in damage to floor surfaces due to nail popping and to shifting of underlayment.

Electricity on the Farm for Utility and Safety, by William H. Knight and J. W. Martin. University of Idaho (Moscow) Farm Electrification Leaflet No. 26 (June, 1954). Information for farmers on circuits and wiring to safely and efficiently carry farm power loads.

Straight Drop Spillway Stilling Basin, by C. A. Donnelly and F. W. Blaisdell. University of Minnesota St. Anthony Falls Hydraulic Laboratory (Minneapolis 14) Technical Paper No. 15, Series B (November 1954). Presents a generalized design based on research, to provide a stilling basin for use with straight drop spillways, which will prevent scouring of the channel downstream from the spillway.

PERSONNEL SERVICE BULLETIN

NOTE: In this bulletin the following listings current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated.

POSITIONS OPEN—AUGUST—O-251-648, 244-649. SEPTEMBER—O-276-650, 262-651, 293-654. OCTOBER—O-326-656, 332-657, 327-659, 353-660. NOVEMBER — O-374-661. 1955 — JANUARY—O-434-666, 437-667, 438-668, 441-669, 442-670, 447-671, 447-672. FEBRUARY—O-2-702, 23-703, 19-704, 32-705, 33-706, 44-707, 44-708, 18-709.

POSITIONS WANTED — AUGUST — W-237-142, 265-144. SEPTEMBER — W-246-147, 266-149, 294-150. OCTOBER—W-296-152, 330-153, 340-154, 365-155. NOVEMBER—W-369-157, 372-159, 375-160. DECEMBER — W-400-161, 391-164, 409-165, 411-166. 1955—JANUARY—W-424-167, 429-168, 427-169. FEBRUARY—W-34-1.

NEW POSITIONS OPEN

SALES ENGINEERS (2) and office engineer for irrigation equipment. Contact dealers and customers. Midwestern territory. BS deg in agricultural engineering, or equivalent. Usual qualifications for sales engineering. Sales experience on irrigation equipment or centrifugal pumps. Excellent opportunity. Salary open, or commission basis. O-55-710

AGRICULTURAL ENGINEER for product design, development and field testing of tillage implements and related farm equipment, with major full-line manufacturer, Midsouth location. Age 25 or over. BS deg in agricultural or mechanical engineering or equivalent and two to three years or more of engineering experience. Farm background helpful but not required. Excellent opportunity for advancement. Retirement, hospitalization and insurance benefits. Salary open, depending on experience and qualifications. O-56-711

EXECUTIVE ENGINEER with design and production know-how in portable irrigation equipment field, with established manufacturer in Midwest. BS deg in engineering with actual design experience on irrigation equipment and ability to get along with people. Excellent opportunity to progress rapidly as product develops. Salary open, executive bracket, with benefits plus profit sharing program. O-15-712.

AGRICULTURAL ENGINEER to head research on improvement in ginning mechanically harvested cotton, at a cotton research station in the Southwest. BS deg in agricultural engineering, or equivalent. Ability to analyze problems and proceed with experimental work. Familiar with cotton ginning or experience with manufacturer of cotton ginning equipment. Opportunity up to individual. Facilities and equipment for project valued at over $100,000. Salary open, depending on training and experience. O-61-713

AGRICULTURAL ENGINEER for teaching and probably some research in irrigation and farm structures in a technological college in the Southwest. Temporary school year appointment effective September 15. Approval expected for summer work and permanent full-time position. Advanced degree preferred. Well-qualified man with BS deg will be considered. Usual personal qualifications for college teaching. Teaching or application experience in subject matter fields desirable. Salary open. O-71-714

SPRINKLER IRRIGATION engineer for design, development and research in field of overhead irrigation. Work consists of lay-out planning, estimates, and personal contact with sales representatives of equipment. Engineering, sales, and farming background necessary requisites. Splendid opportunity for progressive-thinking young man in rapidly expanding industry. Salary open. O-87-715

POSITIONS WANTED

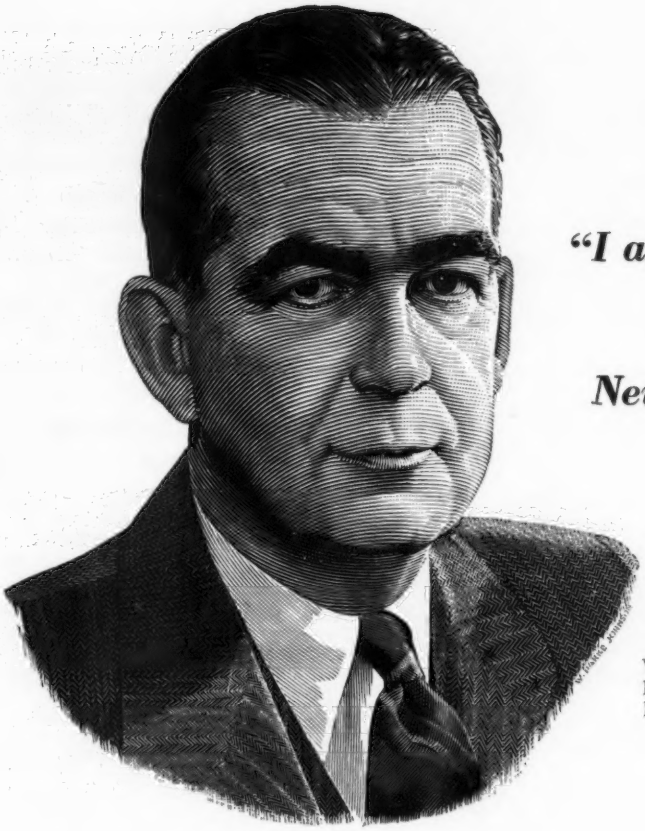
AGRICULTURAL ENGINEER for design development, research, sales, service, or writing in rural electric field with industry, in North Central area. Married. Age 30. No disability. BS deg in agricultural engineering 1949, Michigan State College. Farm background. Electrification adviser for REA Co-op past five years. War service in Navy. Commissioned ensign from U.S. Naval Aviation Cadet program in 1946. Available on reasonable notice. Salary about $4800. W-27-6

AGRICULTURAL ENGINEER for extension, teaching or research in public service or with manufacturer or farming operation, power and machinery or farm structures field, in Florida. Limited travel. Married. Age 26. No disability. BS deg in agriculture, major in agricultural engineering, Macdonald College of McGill University, 1951. Farm work experience in Quebec and New York State. Sales and service work with farm equipment manufacturer, one year. Fieldman with milk company past 3 yr. Available July 15. Salary open. W-17-2

AGRICULTURAL ENGINEER for extension, research, service or management in rural electric field, with industry or public service, in Southwest. Married. Age 32. No disability. BS deg in agricultural engineering expected in May, Oklahoma A & M College. Electrical supply, construction and maintenance work since 1946. Part time electrical maintenance work for college. War service experience in Air Force 2 yr as flight engineer and instructor in aerial gunnery. Available June 15. Salary $5000. W-52-3

AGRICULTUURAL ENGINEER for design, development, research, sales, or service in power and machinery field, with manufacturer, processor, or distributor. Any location. Single. No disability. BS deg in agricultural engineering, 1952, Ohio State University. Part time research in experiment station while in college. Army Corps of Engineers 1953-55. Available now. Salary open. W-48-4

AGRICULTURAL ENGINEER for research, teaching, extension, or development in farm structures, machinery, or processing, with industry, state institution, or private management service, preferably in West. Married. Age 26. No disability. BS deg in agriculture, major in agricultural engineering, 1950, Montana State College. MS deg in agricultural engineering expected in June, University of Idaho. Farm background, including 2 yr full-time farming. Air Force 2 yr, commissioned, partly in maintenance engineering work. One year as instructor in agricultural engineering, one year as research fellow, studying efficiency in potato packing. Available July 1. W-84-5



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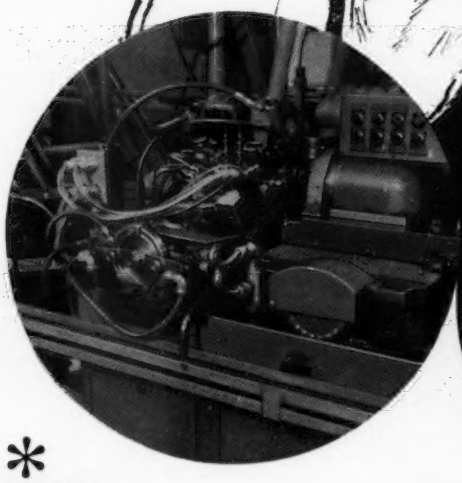

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